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Year Book
No. 29

1930

CARNEGIE INSTITUTION
OF
WASHINGTON

YEAR BOOK No. 29

JULY 1, 1929, TO JUNE 30, 1930

226431

WITH ADMINISTRATIVE REPORTS THROUGH DECEMBER 12, 1930

1902

PUBLISHED BY THE CARNEGIE INSTITUTION OF WASHINGTON
WASHINGTON, 1930

WASHINGTON TYPOGRAPHERS, INC.
SOUTHERN ENGRAVING CO.

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PRESIDENT

John C. Merriam

FORMER PRESIDENTS

*Daniel Coit Gilman, 1902–04 *Robert Simpson Woodward, 1904–20

BOARD OF TRUSTEES

Elihu Root, *Chairman*
Henry S. Pritchett, *Vice-Chairman*
Frederic A. Delano, *Secretary*

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*George J. Baldwin	1925–27	*Samuel P. Langley	1904–06
*John S. Billings	1902–13	*William Lindsay	1902–09
Robert S. Brookings	1910–29	*Henry Cabot Lodge	1914–24
*John L. Cadwalader	1903–14	*Seth Low	1902–16
*Cleveland H. Dodge	1903–23	*Wayne MacVeagh	1902–07
*William E. Dodge	1902–03	*Darius O. Mills	1902–09
*Charles P. Fenner	1914–24	*S. Weir Mitchell	1902–14
Simon Flexner	1910–14	*William W. Morrow	1902–29
*William N. Frew	1902–15	George W. Pepper	1914–19
*Lyman J. Gage	1902–12	Martin A. Ryerson	1908–28
*Daniel C. Gilman	1902–08	*John C. Spooner	1902–07
*John Hay	1902–05	*William H. Taft	1906–15
*Myron T. Herrick	1915–29	*Charles D. Walcott	1902–27
*Abram S. Hewitt	1902–03	Henry P. Walcott	1910–24
*Henry L. Higginson	1902–19	*Andrew D. White	1902–16
*Ethan A. Hitchcock	1902–09	*Edward D. White	1902–03
*Henry Hitchcock	1902–02	*Henry White	1913–27
*William Wirt Howe	1903–09	*Robert S. Woodward	1905–24
*Carroll D. Wright	1902–08		

*Deceased

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904: the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, the President of the National Academy of Sciences.

STAFF OF INVESTIGATORS

Department of Embryology:

Established 1914; Franklin P. Mall, Director 1914-1917.

George L. Streeter, Director
Carl G. Hartman
Chester H. Heuser
Margaret R. Lewis
Warren H. Lewis

Department of Genetics:

Station for Experimental Evolution, opened in 1904, was combined with Eugenics Record Office in 1921 to form Department of Genetics.

Charles B. Davenport, Director
A. F. Blakeslee, Assistant Director
H. H. Laughlin, Assistant Director
A. G. Avery
H. J. Banker
A Dorothy Bergner
M. Demerec
E. C. MacDowell
C. W. Metz
Oscar Riddle
Sophie Satin
M. Steggerda

Geophysical Laboratory:

Organised 1906, opened 1907.

Arthur L. Day, Director
L. H. Adams
Eugene T. Allen
Tom Barth
N. L. Bowen
C. N. Fenner
R. E. Gibson
R. W. Goranson
J. W. Greig
J. H. Hibben
F. C. Kracek
C. J. Ksanda
H. E. Merwin
G. W. Morey
Charles S. Piggot
Eugene Posnjak
H S Roberts
J. F. Schairer
E S. Shepherd
George Tunell
H. S. Washington
Walter P. White
Fred E. Wright
E. G. Zies

Division of Historical Research:

Organised 1903; Andrew C. McLaughlin, Director 1903-1905, J. Franklin Jameson, Director 1905-1928.

A. V. Kidder, Chairman

Section of Aboriginal American History,

Sylvanus G. Morley
Earl H. Morris
H. E. D. Pollock
O. G. Ricketson jr.
H. B. Roberts
Karl Ruppert
A. Ledyard Smith

Section of United States History:

Edmund C Burnett
Waldo G. Leland
Charles O. Paullin
France Scholes
Leo F. Stock

Section of the History of Science:

George Sarton
Alexander Pogo

Associated Investigators:

W. A. Heidel
Elias A. Lowe

Department of Meridian Astrometry:

Established 1907; Lewis Boss, Director 1907-1912.

Benjamin Boss, Director
Sebastian Albrecht
Sherwood B. Grant
Heroy Jenkins
Harry Raymond
Arthur J. Roy
W. B. Varnum
Ralph E. Wilson

Mount Wilson Observatory:

Established 1904; George E. Hale, Director 1904-1923

George E. Hale, Honorary Director
Walter S. Adams, Director
F. H. Seares, Assistant Director
Alfred H. Joy, Secretary
A. S. King, Supt. Physical Laboratory
J. A. Anderson
Harold D. Babcock
Theodore Dunham jr.
Ferdinand Ellerman
Edwin P. Hubble
Milton L. Humason
Paul W. Merrill
Seth B. Nicholson
Francis G. Pease
Edison Pettit
R. F. Sanford
Sinclair Smith
Charles E. St. John (Retired)
Gustaf Strömberg
A. van Maanen

Nutrition Laboratory:

Organized in 1907, opened 1908.

Francis G. Benedict, Director
T. M. Carpenter
V. Coropatchinsky
E. L. Fox

Division of Plant Biology:

Desert Laboratory, opened in 1903, became headquarters of Department of Botanical Research in 1905. Name changed to Laboratory for Plant Physiology in 1923, and reorganized in 1928 as Division of Plant Biology, including Ecology.

H. M. Hall, Acting Chairman
John Belling
Ralph W. Chaney
Frederic E. Clements
F. W. Haasis
Frances L. Long
Daniel T. MacDougal
H. W. Milner
Forrest Shreve
James H. C. Smith
H. H. Strain
George R. Wieland

Department of Terrestrial Magnetism:

Organized 1904.

Louis A. Bauer, Director Emeritus
J. A. Fleming, Acting Director
A. A. J. Crowne
O. Dahl
F. T. Davies
C. R. Duvall
V. J. Eaton
H. M. W. Edmonds
C. C. Ennis
H. W. Fisk
S. E. Forbush
R. E. Gebhardt
O. H. Gish
H. W. Graham
John W. Green
L. R. Hafstad
C. Huff
H. F. Johnston
P. G. Ledig
A. G. McNish
Wilfred C. Parkinson
W. J. Peters
W. J. Rooney
W. E. Scott
S. L. Seaton
K. L. Sherman
F. M. Soule
Oscar W. Torreson
M. A. Tuve
G. R. Wait
W. F. Wallis
F. W. Wood

Investigators at Tortugas Laboratory, Summer 1930:

W. E. Bullington, Randolph-Macon College
L. R. Cary, Princeton University
P. S. Conger, Carnegie Institution of Washington
Haldane Gee, Scripps Institution of Oceanography
J. N. Gowanlock, Dalhousie University
Caswell Grave, Washington University (St. Louis)
D. L. Hopkins, Duke University
W. H. Longley, Goucher College
H. W. Manter, University of Nebraska

Investigators at Tortugas Laboratory, Summer 1930—Continued:

Gordon Marsh, University of Texas
A. A. Schaeffer, University of Kansas
Waldo L. Schmitt, U. S. National Museum
J. P. Visscher, Western Reserve University
Shigeo Yamanouchi, University of Tokyo

Other Investigators:

Albert Mann, Research Associate in Biology
Harry O. Wood, Research Associate in Seismology

Additional Research Associates connected with other Institutions:

E. B. Babcock (University of California), Genetics
A. M. Banta (Brown University) Genetics
V. Bjerknes (University of Oslo, Norway), Meteorology
J. P. Buwalda (California Institute of Technology), Palæontology
W. E. Castle (Harvard University), Biology
H. L. Clark (Harvard University), Biology
K. T. Compton (Massachusetts Institute of Technology), Spectroscopy
H. E. Crampton (Columbia University), Biology
A. E. Douglass (University of Arizona), Ecology
Walter Eddy (Columbia University), Physiological Chemistry
H. M. Evans (University of California), Nutrition
R. H. Goddard (Clark University), Physics
E. Newton Harvey (Princeton University), Biology
J. H. Jeans (Royal Society of London), Astronomy
W. Jochelson (American Museum of Natural History), Archæology
Remington Kellogg (U. S. National Museum), Palæontology
A E. Kennelly (Harvard University), Terrestrial Magnetism
L. B. Mendel (Yale University), Physiological Chemistry
A. A. Michelson (University of Chicago), Astronomy
T. H. Morgan (California Institute of Technology), Biology
A. T. Mussen (Johns Hopkins University), Physiology
A. A. Noyes (California Institute of Technology), Chemistry
Greenleaf W. Pickard, Terrestrial Magnetism
Henry A Ruger (Columbia University), Psychology
G. Oscar Russell (Ohio State University), Physiology
Henry N. Russell (Princeton University), Astronomy
Chester Stock (California Institute of Technology), Palæontology
H. U. Sverdrup (Geofysisk Institut, Bergen, Norway), Terrestrial Magnetism
H. B. Vickery (Connecticut Agric. Exper. Station), Physiological Chemistry
J. E. Weaver (University of Nebraska), Ecology
Lewis H. Weed (Johns Hopkins University), Anatomy
David White (National Academy of Sciences), Palæontology
R. R. Williams (Bell Telephone Laboratories), Physiological Chemistry
Bailey Willis (Stanford University), Seismology
Clark Wissler (American Museum of Natural History), Archæology

ORGANIZATION, PLAN AND SCOPE

The Carnegie Institution of Washington was founded by Mr. Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him January 19, 1911; so that the present endowment of the Institution has a par value of twenty-two million dollars. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution,* articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington.* (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President

The Articles of Incorporation of the Institution declare in general "that
of the Institution as chief executive officer.
the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

ARTICLES OF INCORPORATION

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) If general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, *Samuel P. Langley,* William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, *Ethan A. Hitchcock,* Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott,

Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold, and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcot, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

ARTICLE I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacanies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

ARTICLE II

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

ARTICLE III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

Article IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

Article V.

COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

ARTICLE VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures of the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

ARTICLE VII.

AMENDMENT OF BY-LAWS

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES OF THE THIRTY-FIRST MEETING OF THE BOARD OF TRUSTEES

ABSTRACT OF MINUTES OF THE THIRTY-FIRST MEETING OF BOARD OF TRUSTEES

The meeting was held in Washington in the Board Room of the Administration Building on Friday, December 12, 1930. It was called to order at 10 a. m. by the Chairman of the Board, Mr. Root.

Upon roll-call the following Trustees responded: W. W. Campbell, Frederic A. Delano, Cass Gilbert, Frederick H. Gillett, Andrew J. Montague, Wm. Church Osborn, Stewart Paton, John J. Pershing, Henry S. Pritchett, Elihu Root, William Benson Storey, W. S. Thayer, William H. Welch, and George W. Wickersham. The President of the Institution, John C. Merriam, was also present.

The minutes of the thirtieth meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Directors of Departments and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1931 were authorized:

Pension Fund	$ 50,000
Administration	72,050
Publication (including Division of Publications)	104,390
Departments and Divisions of Research	1,247,879
Minor Grants	135,500
General Contingent Fund	70,000
Special Emergency Reserve Fund	50,000
	1,729,819

The resignation of W. Cameron Forbes as Secretary of the Board of Trustees was accepted with regret.

Mr. Root was re-elected Chairman of the Board of Trustees, Mr. Pritchett was re-elected Vice-Chairman and Mr. Delano was elected Secretary of the Board.

Messrs. Parsons, Paton and Pritchett were re-elected members of the Executive Committee for a period of three years. Messrs. Pritchett (Chairman) and Wickersham were reelected members of the Finance Committee for a period of three years, and Mr. Osborn was elected to take the place of Mr. Parsons as a member of this Committee for the same period.

Messrs. Parmelee (Chairman), Delano and Storey were re-elected members of the Auditing Committee for a period of three years.

The meeting adjourned at 12:15 p. m.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1930

WASHINGTON TYPOGRAPHERS, INC.
WASHINGTON, D. C.

REPORT OF THE PRESIDENT
OF THE
CARNEGIE INSTITUTION OF WASHINGTON

In conformity with Article IV, section 2, of the By-Laws of the Carnegie Institution of Washington, the President has the honor to submit the following report on work of the Institution for the fiscal year ending **October 31, 1930,** together with provisional recommendation of appropriations for the year beginning January 1, 1931.

James Percy Ault

Through destruction of the ship *Carnegie* in the harbor of Apia on November 29, 1929, the Institution suffered loss of James Percy Ault, to whom we owe a large measure of the result obtained through many expeditions of the vessel. As commander of the *Carnegie* on its third, fourth, sixth and seventh cruises, and as one of the members of the staff most intimately concerned with development of researches conducted through use of this unique instrument, Captain Ault had made for himself a high place in the field of investigations in terrestrial magnetism and oceanography.

No finer tribute to the work of Captain Ault can be made than that presented through the following words of his colleagues on occasion of the exhibition of results of research of the Institution which occurred immediately after the loss of the ship *Carnegie.*

In the work of development, and in all of the accomplishments of the *Carnegie*, Captain Ault had a leading part. The studies of physics of the earth carried out on the vessel are a monument to his interest and ability. He had qualities of leadership peculiarly adapted to a program of such exceptional difficulty as that represented in long-continued research under conditions of comparative isolation obtaining on a ship at sea.

Possessed of high ideals and sterling character, and with a genial, lovable personality, Captain Ault was held in highest regard by his associates. His devotion to the work in which he was engaged set an example that had wide influence.

As one of America's pioneers in the field of oceanography, Captain Ault made a contribution which will live as long as the search for truth continues.

End of the *Carnegie* Cruise

As major research enterprises of the Institution, the seven cruises of the ship *Carnegie* have constituted one of the most important of all field activities. Termination of this long series of observations through destruction of the vessel at Apia on November 29, 1929, brought to instant halt comprehensive plans for magnetic and general oceanographic work which had been carried on through more than twenty years.

With all of the great loss entailed in destruction of the ship and the death of its distinguished commander, Captain Ault, it is important to recognize that the same interest in development of this program which had been expressed in extension of the work over these many years had guarded, so far as might be possible, the values already obtained. The plans of the Department of Terrestrial Magnetism were so organized as to give clear statement of relations of any activity to what preceded and what followed. Discussion of activities of the department, as they were presented on board the *Carnegie*, at San Francisco, on the eve of departure for the last voyage, brought out in striking manner the close relation between accumulation of observational data and theoretical interpretation of the results. The addresses of Dr. Pritchett, Dr. Campbell, Captain Ault, and Dr. Adams, published in connection with the annual report of 1929, present an interesting statement of the work of the vessel in its relation to the program of the Institution as a whole.

Unlike destruction of property in many other forms, loss of the *Carnegie* meant halting of specific plans, for immediate continuation of which material equipment could not be made available within the period for which the observations were to be conducted. It remained only to accept the end of this voyage as a point to which the most careful possible study of observational and theoretical results should be carried as early as possible. Through extraordinarily rapid reorganization of plans for study, and with most intense concentration upon problems at hand, the Department of Terrestrial Magnetism proceeded to bring to a stage of interpretation the results of work on the vessel up to the time of its entering the harbor at Apia. Practically every item of information, and all important materials gathered for scientific study, were immediately available. Much of the data has now been studied, and, in part, the results have been placed at the disposal of the scientific world.

Activities of the Department of Terrestrial Magnetism directed toward accumulation of observational data have been correlated with fundamental research on theoretical and experimental physics. These types of study have been conducted in close relation to each other and to the observational work on the earth as a whole.

Terrestrial Magnetism and Atomic Physics

Within the past year important advances have been made in experimental investigations on the side of atomic physics. Of much significance in this connection is the accord between experimental results and theoretical prediction. Through the work of Dr. Tuve, Mr. Hafstad, Mr. Dahl, and the closely associated studies of Dr. G. Breit, it has been possible to develop vacuum tubes operating reliably at potentials up to two million volts, and to obtain measurements of the magnetically deflected high speed electrons (artificial beta rays) and also the penetrating X-rays (artificial gamma rays). As supplementing results of investigation in other laboratories of this country and Europe, these contributions have real significance in the attempt to obtain an understanding of those fundamental physical phenomena expressed through terrestrial magnetism.

In the past year it has been the privilege of the Institution to participate in an effort to further certain aspects of physical research which offer possibility of opening a very large field for scientific investigation. Through support of Clark University, and with significant contribution over many years by the Smithsonian Institution and other agencies, Dr. R. H. Goddard of Clark University has conducted a series of important studies on rocket propulsion. It has been hoped that a controlled projectile might be lifted to high levels of the atmosphere and thus make it possible to obtain further knowledge regarding outer regions of the earth's envelope.

Contribution by the Institution, corresponding to that of the Smithsonian Institution, for these studies of Dr. Goddard has been followed by more extended private support of this work. The intensive study of the problem is now being aided, so far as possible, by correlated effort from various departments of the Institution and by other agencies. It is hoped that if it becomes possible to reach the upper regions of the atmosphere with a controlled rocket, apparatus may be available through which important observational data can be obtained. Attainment of Dr. Goddard's objective would offer an important avenue for advance of research in terrestrial magnetism and atmospheric electricity, as also in astronomical investigations.

Exceptional Opportunities for Research Development

However clearly defined a research program may be, successful conduct of investigation inevitably raises a multitude of new questions. The past year's work of the Institution, reviewed in the Year Book for 1930, outlines many such problems. Some are general and some specific. Their solution depends upon new plans, new equipment, new personnel, or additional financial support. This view presents an extremely interesting range of opportunity in research adventure.

Among the possibilities for important new work in the physical sciences there is in the program of Mount

Wilson Observatory the problem of extending study of the spectrum of stars into regions of the ultra-violet where researches have not yet been practicable.

Another case of much needed investigation, involving both scientific and technical aspects, is presented in the enormous field which would be opened by successful refinement of photographic emulsions, so as to permit the accurate recording of more delicate visual elements than can be obtained by the best available photographic plates. The limit of observation of remote bodies in space is determined by the character of light impressions. If the amount of light received for a given moment of observaton is small, multiplication of the time, or refinement of the photographic plate, may make it possible for the telescope and the photographic apparatus to make record of what would otherwise be unattainable. Concentrated attention upon development of apparatus of this nature might increase greatly the opportunities for astronomical research, and, in fact, for investigation throughout the physical sciences.

Another opportunity of first rank within the Institution touches the possibility of extending to the sky of the Southern Hemisphere the work of Mount Wilson Observatory concerned with outlying regions of space examined in study of the nebulæ and objects of corresponding significance. The researches of Dr. Hubble and others, through use of the 100-inch telescope, have made large contribution in one of the most important fields for interpretation of the fundamental nature of the universe. A considerable part of observable space represented by the southern sky is shut off from observation at Mount Wilson. Data for the whole field of stars and nebulæ becomes of instant importance when considered in the light of the program upon which the Institution has been engaged. The opening of opportunity for these investigations is one which presents a certainty of large result in study of questions of great scientific and human interest.

As a part of the regular program of solar research at Mount Wilson, another problem of outstanding importance relates to study of the intensity of lines in the spectrum of the sun. Attention has already been turned to this work, and its further development awaits completion of physical apparatus necessary for these investigations.

As concerning the opportunity for furtherance of studies at Mount Wilson Observatory, it is important to realize that nearly all of the major and minor investigations under way depend in considerable measure upon adequacy of equipment and effectiveness of laboratory facilities. Further development of the research program will require that addition be made to existing quarters and, in some measure, to available equipment.

Other important opportunities for extension of research lie in the program of the Geophysical Laboratory. These studies center upon experiments relating to influence of high temperatures and high pressures upon rock-forming materials, and are designed to interpret conditions under which rocks in the outer part of the earth's mass have been made. They supplement researches on rocks already formed at the surface of the earth, and on others once deeply buried, but now uncovered by erosion and available for examination.

Researches in this region of high pressures have been carried on for more than twenty years in the Geophysical Laboratory, and their contribution to science is large. Under existing conditions of equipment experimentation has reached the limits of safety. An important field lies just out of reach. A staff with extremely valuable experience is available for further investigation. Extension of the work is not possible without considerable addition to the present building and equipment. This opportunity is one of exceptional importance for geological and physical science.

The Department of Terrestrial Magnetism feels that there is urgent need for installation of equipment for radio transmission at its Huancayo station in Peru. Many phases of investigation in the field of magnetism concern conditions of the upper atmosphere. Some of the most interesting researches of recent years have related to examination of the Heaviside layer. These studies are an essential part of discussion of the major problem of the department, as it concerns the earth alone and as it touches relation of the sun to the earth. There would be a further important use for such apparatus in that it would give instant communication with the central office in Washington. At the same station the Department of Terrestrial Magnetism has recommended installation of seismological recording apparatus for securing information concerning both local and distant earthquakes in the Southern Hemisphere. This proposal is approved by the Chairman of the Institution's Advisory Committee in Seismology. It is important to note in this connection that seismological researches with which the Institution has been connected have touched the Southern Hemisphere, and that such a station as is proposed would have much value in examination of seismological phenomena concerning the earth as a whole.

In the field of biology, the bringing together of several groups of investigations in biology of plants has shown that furtherance of researches under way requires emphasis upon certain connecting phases. So, it is evident that extremely interesting relations between the work of Dr. Hall on taxonomy or classification of plants, and that in other studies upon influence of environment and heredity require concentration upon special aspects of research. Particularly important is it to add to this staff a small group of investigators concerned with study of the cell and interested particularly in several aspects of heredity.

In connection with advance of investigations in the field of factors in animal development, there is need for extending the opportunity of several departments, including Embryology, Genetics, and Nutrition, by increasing the size of the animal colony at the Department of Embryology. The work being done by Dr. Hartman in physiology and animal development through use of the macaque colony presents some of the most interesting known research opportunities. Advance of these investigations would mean progress in several of the most fundamental fields of biological research. Furtherance of this work also offers wider possibilities for cooperation with research workers at other institutions, especially with the important group at Johns Hopkins University.

Conferences on Factors in Animal Development

Close relation of activities in several departments of the Institution concerned with factors of animal development has led to initiation of a series of conferences including the departments of Genetics, Embryology, Nutrition, and Tortugas Laboratory, together with investigators from other departments or divisions of the Institution intimately concerned with these questions.

Discussion of the program of each of the departments in the light of interests of other investigators has illuminated the field of each group and has brought out relationship of activities which are really intimately connected, although conducted in widely separated laboratories. The stimulus to research in the field of animal biology has been important in all aspects of investigation, and the contacts developed through cooperation on projects of mutual interest have been extremely helpful.

Meetings have been held at each of the laboratories in the Institution at which research in the field of animal biology is under way. The development of these interrelated activities has not been carried out with the idea of limiting the extent of cooperation with other agencies, but rather with the feeling that such wide contact as has been had with other types of institutions will be materially strengthened by such relationships within the Institution.

No better illustration of advantage in this type of organization can be found than in the touch of other groups with investigations in the Department of Embryology. The field, as visualized in this department, involves the whole series of factors in development, ranging from the incipient changes of the egg through the period of birth and early development. The studies in problems of genetics, physical and chemical constitution of the egg and varying stages of the embryo, the problem of tissue growth, questions which relate to physiological changes in the embryo, and the development of glands which control various physiological functions, all come to have increased significance when viewed in the light of corresponding investigations in other departments.

Correlated Investigations In Central Africa

In course of the past year the Institution has had opportunity to conduct a group of four investigations in Central Africa. Although apparently widely separated, these studies have a relation each to the other which is brought out by study of the basic factors in each. They concern, on the one hand, great movements of the earth's crust, in the so-called Rift Region of Africa, as expressed in seismic and in volcanic activity possibly related to these great crustal changes. Another group of investigations was made possible by opportunity offered for study of habits and psychology of a type of gorilla inhabiting a portion of the area which was examined because of its interesting volcanological story. In still another related region there was study of geographical distribution of certain groups of animals considered with special reference to the geological factors which have influenced distribution or migration.

Through courtesy of the Government of Belgium and the Government of Great Britain, the expeditions in which the Carnegie Institution participated found exceptional facilities for researches in this region.

The party consisting of Dr. Willis, of Stanford University, concerned with seismology, and Dr. Bowen, of our Geophysical Laboratory, interested in volcanology, covered a large area, and also had opportunity to discuss the peculiar problems of this region at the International Geological Congress at Pretoria.

The expedition for study of habits and psychology of the gorilla secured interesting and important data bearing upon one of the best opportunities for field research on animal behavior. The rather sharply defined area of distribution of the gorilla, and the possibility opened for protection of this race, had led to the establishment by the Government of Belgium of a reservation known as *Parc National Albert,* set aside for purposes of scientific study. The brief contact which it was possible for Dr. Bingham to have with the gorilla colonies was sufficient to make clear the very great contribution made to opportunity for research through reservation of this area by the Government of Belgium. It helped also to point out the significance of this opportunity for psychological study of a group of animals having many peculiarities resembling those of man, and yet remaining in a state of complete primitiveness as to all conditions of environment.

Problems in History of Life

Discussion of laws underlying the history of life as it is seen through the ages has had a part in activities of the Institution from the beginning of its program. The significance of this problem was clear to Dr. Charles D. Walcott, who, as a distinguished student in this field, was one of the founders of the Institution. Outstanding contribution to research in this subject has been made by Case, Williston, Moodie, Hay and others. Especially important has been the group of investigations dealing with that critical period between the age of amphibians and the age of reptiles, relating to a time when the great group of mammals now dominating the earth had not yet been developed.

During the past year, activities of the Institution in support of studies on the history of life have included extremely significant work by Dr. Remington Kellogg, on evolution of the whales and other marine mammals, by Dr. Chester Stock, Dr. John P. Buwalda, Dr. Loye Miller, Mr. E. L. Furlong, and others on leading questions relating to history of life in the age of mammals. Contributions of Dr. Ralph Chaney on the history of plants in the later geological periods, and of Dr. David White on earlier floras have been among the most important in this field of investigation.

In addition to researches on occurrence, history, and evolution of specific groups of animals and plants, it is interesting to note that the Institution is now giving support for studies on two of the greatest problems in history of life. One relates to the beginnings of life; the other to beginnings of human history in America. The first is concerned in studies of Dr. David White on remains from the earliest unaltered rocks of Grand Canyon. The second is involved in the investigation of Gypsum Cave, Nevada, where human remains are found in such situation as to raise question concerning their association with life strange to the present fauna of the earth. The work at Gypsum Cave is carried on by M. R. Harrington under auspices of the Southwest Museum, and in association with Dr. Chester Stock of California Institute of Technology.

Division of Historical Research

Organization of investigations in the newly established Division of Historical Research has developed in most effective manner through operations of the past year. Combined interest of the groups engaged in historical studies has made possible development of an extremely important constructive agency for research on development of ideas and institutions. The several viewpoints in historical research, such as those concerning aboriginal Americans, institutions transplanted to this continent from Europe, and the advance of civilization seen through the history of science, have given us an appreciation of growth in human institutions not easily obtained by other means.

One of the most interesting studies on events in early American history is found in the researches of Dr. Ricketson, touching relation of the so-called Archaic culture of Middle America to the typical Maya civilization. In another direction, investigation of the whole problem of Maya civilization through study of the present-day life, culture, and environment of the people of these areas, is one of the most clearly logical programs for development of historical research that has been set up in any country.

Relation to the Public

Experience of the Institution in activities directed toward interpretation of materials obtained in our investigations indicates that there is large value to the scientific and lay public in simple and clear statement of results secured. The increased contribution of the Institution through this type of activity compares favorably in some respects with that attained through publication of technical monographs. Evidence of value in this work does not diminish responsibility of the Institution for making its investigations as fundamental, as accurate scientifically, and as logical philosophically as possible. It indicates only the need for more intensive study of this problem than has been possible heretofore.

It is clear that, with our exceptional opportunities, relation to the public involves more than the responsibility merely to conduct researches. The basic objective involved in advancement of knowledge for improvement of mankind evidently comes nearer to attainment when publication of detailed conclusions is accompanied by a certain measure of interpretation of the materials secured.

The attempts to meet our responsibility for interpretation of research results through exhibits, lectures, general releases, and in other ways, have brought such a response as to indicate that extension of this opportunity in several directions would be profitable. It is also evident that betterment of methods used, simplification of types of statement, and further study of the ways in which human interest values can be realized, would make important contribution.

To carry out a program corresponding measurably to the opportunity of the Institution, it is necessary that quarters be made available which would give rooms for conference of groups of Institution investigators along with representatives of other agencies. There should be available a small group of offices which could be used for visitors engaged upon study of special questions. It is necessary also to have an auditorium of modest dimensions, which would accommodate audiences interested in the type of presentation of research results which has been carried forward successfully in recent years. Development of equipment of this nature should include some extension of the quarters designed for handling of publications of the Institution, including both technical monographs and those contributions which have to do with interpretation of our results.

Determination of policy of the Institution with reference to these matters probably represents one of the most important questions for consideration at the present moment. Adequate expression of this aspect of work of the Institution may not be considered as indicating trend of interest away from fundamental research activities. It is to be thought of only in the light of means through which work done by the Institution may attain a relatively high value for the scientific world, and also for the interested public. It is probable that long-continued research activity without attempt to offer means for interpretation would definitely reduce the value of results obtained by the Institution.

The tendency of modern science, philosophy, and education is to recognize that advance of knowledge does not depend merely upon accumulation of facts. There is involved, as one of the most important features, the relation of these facts to others, and such a degree of interpretation as will permit attainment of their largest human value.

Restudy of Pensions and Insurance

Continuity in effective work of any widely extended activity is possible either where there are no losses and no unforeseen circumstances, or where, through careful planning, provision is made against calculable losses, wear, age, and other roughly predictable factors. The general plan of the

Institution includes provision for protection of the individual and of property.

With increasing refinement of actuarial theory and practice it has been recognized as important to keep under constant review various aspects of our pension program, and of various forms of insurance established by the Institution.

The pension system, established in 1919, carries certain unusual features based upon the fact that at the time it was set up a group of members had already served for more than fifteen years, and were not in position to accumulate sums sufficient to pay adequate retiring allowances. Recognizing past service, a plan was put into operation by which such cases might be covered through supplementary annuities providing retirement allowances comparable to amounts which would be obtained if the pension system had been established earlier. The pension program as it now operates requires relatively large expenditures on the part of the Institution for the period in which supplementary annuities must be provided. Recent studies of the plan have been devoted specifically to consideration of the extent to which the Institution should contribute toward the Pension Fund in order to give adequate support for the whole system, including supplementary annuities for which arrangement has already been made.

In connection with study of the general pension plan, attention has been given to the possibility of opening opportunity for continuing intellectual activity to those who have retired. In many cases such post-retirement service offers possibility of obtaining the value of highly trained minds where interest in great questions is undiminished and freedom from restraint of regular work may mean stimulus to creative study of large importance. It is interesting to note that among the great figures of the world, not merely in science and in learning, but in the most strenuous types of human activity, many leaders of thought and action are far beyond what is assumed to be the retiring age in any regularly organized pension system.

Salary Increases

In the past year the problem of salary scale in relation to cost of living, to income of the Institution, and in contrast to salaries of other comparable agencies has presented one of our most difficult problems. The effort to make possible for the staff a scale of living corresponding to that of other investigators and contributors to knowledge has required increased draft upon our income.

In the past ten years the Institution has added to its salary roll approximately $280,000. With the proposed additions for 1931 the amount will be near $312,000. This is the interest on more than six million dollars, and equals the income of three millions received from Carnegie Corporation, plus that from the three million dollars of the Reserve Fund on which interest became available in 1921. And yet, with all the effort that has been made, the scale of salary of a staff approximately the same in number over the past ten years, is, at the moment, considerably below that of institutions requiring workers of corresponding competence and activity in creative work.

During the past four years there has been held as available for Emergency Reserve purposes the interest on one million dollars, or $50,000 per year. Of the remaining interest from the sum of eight million dollars which has become available within the past few years, a further $50,000 has been utilized in development of outstanding features in the research program of the Institution.

FINANCIAL STATEMENT

Financial Statement for Fiscal Year 1929–1930

The sources of funds available for expenditure during the fiscal year (including appropriations made by the Trustees, December 13, 1929, and revertments and transfers made during the year), the amounts allotted by the Executive Committee during the year, and the balances unallotted at the end of the year are shown in detail in table A.

A—*Financial statement for fiscal year ending October 31, 1930*

	Balances unalloted Oct. 31, 1929	Trustees' appropriation Dec. 13, 1929.	Revertments and transfers Nov. 1, 1929 to Oct. 31, 1930.	Total available 1930	Executive Committee allotments 1930.	Transfers by Executive Committee.	Unalloted balances Oct. 31. 1930.
Large Grants.							
Embryology		$ 61,260		$ 61,260	$ 61,260		
Genetics		140,000	$3,666 67	143,666 67	143,666.67		
Geophysical Laboratory		180,384	8,000	188,384	188,384		
Historical Research		122,600	19,900	142,500	142,500		
Tortugas Laboratory		15,000		15,000	15,000		
Meridian Astrometry		39,390		39,390	39,390		
Mt. Wilson Observatory		242,665	2,290	244,955	244,955		
Nutrition Laboratory		51,330	2,000	53,330	53,330		
Plant Biology		126,430	6,900	133,330	133,330		
Terrestrial Magnetism		242,250	8,900	251,150	251,150		
Minor Grants	$577.22	148,000	29,403.50	177,980.72	177,800		$180.72
Publications	9,861.18	97,010	3,362.13	110,233.31	101,580 75		8,652.56
Administration		68,650	5,500	74,150	74,150		
Pension Fund		50,000		50,000	50,000		
General Contingent Fund	13,819 50	81,500	35,666	130,985.50	8,522.06	$72,506.67	49,956.77
Sp'. Emer , Reserve Fund		50,000		50,000	50,000		
	24,257 90	1,716,469	125,588 30	1,866,315.20	1,735,018.48	72,506 67	58,790.05

Receipts and Expenditures of the Institution to Date

The aggregates of receipts from interest on endowment, from interest on bond investments and bank deposits, from sales of publications, from refunds on grants, and from miscellaneous sources, for each year since the foundation of the Institution are shown by table B; the grand total of these to date is $73,221,130.21.

B—*Aggregate of financial receipts*

Year ending Oct. 31.	Interest on endowment	Interest on bonds and bank deposits	Sales of publications	Refunds on grants	Miscellaneous items	Total
1902	$250,000 00	$9.70			$1,825.52	$251,835.22
1903	500,000 00	5,867.10	$2,286.16		101.57	508,254.83
1904	500,000.00	33,004.26	2,436.07	$999.03		536,439.36
1905	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068.84
1907	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908	550,000.00	17,761.55	7,877.51	25.68	48,034.14	623,698.88
1909	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910	600,000.00	10,422.78	10,470.25	1,319.29	54,732.45	676,944 73
1911	975,000.00	14,517 63	10,892.26	4,236.87	923.16	1,005,569.97
1912	1,100,000.00	31,118.41	11,496.13	1,658.88	96,035.01	1,240,308.42
1913	1,103,355.00	46,315.60	12,208.66	3,227.53	345,769.95	1,510,876.74
1914	1,105,084.17	59,298.63	11,402.40	7,819.70	577,305.77	1,760,910.67
1915	1,100,375 00	67,888.31	10,297.79	8,322.87	28,162 79	1,215,046.76
1916	1,100,375.00	83,626.38	12,544.16	1,450.12	153,204.40	1,351,200.06
1917	1,100,408.75	100,702.60	11,921.35	32,950.22	179,611.97	1,425,594.89
1918	1,110,427.45	120,464 02	9,921.00	39,833.23	255,354.60	1,536,000.30
1919	1,112,441.25	138,700.73	12,837.58	53,549.98	214,498.99	1,532,028.53
1920	1,112,441.25	159,559.03	18,393.79	4,088.63	176,249.81	1,470,732.51
1921	1,112,441.25	170,211.22	16,684.51	4,068.69	210,518.96	1,513,924.63
1922	1,112,504.52	175,021.09	14,081.84	9,395.66	34,527.38	1,345,530.49
1923	1,114,541.13	192,287 72	13,841.76	9,739.17	1,720,808.90	3,051,218.68
1924	1,115,187.58	193,368.98	11,994.21	18,663.38	409,712.28	1,748,926.43
1925	1,181,585.00	197,696.51	13,680.74	14,315.03	825,156.17	2,232,433.45
1926	1,156,795.00	199,418.02	14,039.02	44,766.64	167,898.35	1,582,017.03
1927	1,186,397.70	199,038.63	10,032.42	19,049.80	1,814,461.93	3,228,980.48
1928	1,496,737.48	218,755.01	10,924.25	31,144.42	26,068,636 68	27,826,197.84
1929	1,376,398 03	217,269.74	8,925.91	110,724.28	6,367,398.68	8,080,716.64
1930	1,373,301 41	271,608.25	9,468.94	61,767.38	1,922,049.30	3,638,195.28
Total	27,645,796.97	3,014,576.68	293,255.51	490,772.71	*41,776,728.34	73,221,130.21

*Of this amount $35,713,637.87 came from the sale of bonds; $52,015.74 from the Colburn Estate; and $5,906,083.34 from the Carnegie Corporation of New York.

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be classified under five heads: (1) Investments in bonds; (2) large projects; (3) minor grants and payments from Pension, Insurance, and General Contingent Funds; (4) publications; (5) administration. Table C shows the actual expenditures under these heads for each year since the foundation of the Institution.

C—*Aggregate of expenditures*

Year ending Oct 31	Purchase of bonds	Large projects	Minor grants and payments from Pension, Insurance, and General Contingent Funds	Publications	Administration	Total
1902	.	. .	$4,500.00		$27,513.00	$32,013.00
1903	$100,475.00		137,564.17	$938.53	43,627.66	282,605.36
1904	196,159.72	$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905	51,937.50	269,940.79	149,843.55	21,822,97	37,208.92	530,753.73
1906	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908	68,209.80	448,404.65	61,282,11	49,991.55	48,274.90	676,163.01
1909	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910	57,889.15	427,941.40	83,464.63	49,067.00	44,011.61	662,373.79
1911	51,921.79	454,609.75	72,048.80	37,580.17	45,455.80	661,616.31
1912	436,276.03	519,673.94	103,241.73	44,054.80	43,791.13	1,147,037.63
1913	666,428.03	698,337.03	110,083.06	53,171.59	43,552.89	1,571,572.60
1914	861,864.23	817,894.52	107,507.55	44,670.55	44,159.54	1,876,096.39
1915	206,203.21	770,488.58	109,569.37	46,698.56	48,224.04	1,181,183.76
1916	473,702.70	638,281.41	99,401.26	73,733.38	49,454.08	1,334,572.83
1917	502,254.05	695,813.07	100,746.13	62,884 61	48,766.29	1,410,464.15
1918	528,565.55	693,780.00	170,470.74	44,394.83	49,118.76	1,486,329.88
1919	438,960.29	845,123.82	203,810.84	68,964.23	55,742.83	1,612,602.01
1920	464,279.57	876,437.28	159,633.49	95,933.10	68,739.90	1,665,023.34
1921	109,390.25	981,186.46	171,895.22	81,388.33	58,730.11	1,402,590.37
1922	50,431.05	975,149.20	192,325.46	96,227.01	56,405.15	1,370,537.87
1923	1,715,537.72	930,395.95	232,344.69	89,402.06	63,493.46	3,031,173.88
1924	440,921.24	939,739.67	230,291.90	87,790.74	65,076.47	1,763,820.02
1925	861,583.20	979,615.36	225,307.45	103,531.67	67,266.71	2,237,304.39
1926	178,817.80	1,060,525.36	254,977.20	84,526.23	65,871.48	1,644,718.07
1927	1,623,071.17	1,164,136.05	258,709.17	85,221.42	67,283.11	3,198,420.92
1928	26,010,438.19	1,208,942.20	281,308.76	93,571.02	73,052.60	27,667,312.77
1929	6,428,356.99	1,341,868.84	324,121.39	95,164.52	69,549.41	8,259,061.15
1930	1,864,870.66	1.264,258.33	274,811.52	113,254.12	73,437.13	3,590,631.76
Total	44,570,316.24	20,429,934.37	4,590,810.01	1,783,387.90	1,528,693.48	72,903,141.00

Investments in Property

On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings and equipment of departmental establishments, the following sums have been expended since the foundation of the Institution:

D—*Real Estate and Equipment, Original Cost*

Administration (October 31, 1930):		
Washington, D. C.		
Building, site and equipment		$342,332.60
Division of Plant Biology (September 30, 1930):		
Palo Alto, Calif.		
Buildings and grounds	$158,044.60	
Laboratory	39,890.47	
Library	16,966.86	
Operating appliances	18,886.14	
		233,788.07
Department of Embryology (September 30, 1930):		
Baltimore, Md.		
Library	2,467.63	
Laboratory	11,068.10	
Administration	6,415.53	
		19,951.26
Department of Genetics (September 30, 1930):		
Cold Spring Harbor, Long Island, N. Y.		
Buildings, grounds, field	284,091.73	
Operating	24,018.94	
Laboratory apparatus	17,423.19	
Library	33,651.44	
Archives	45,488.90	
		404,674.20
Geophysical Laboratory (September 30, 1930):		
Upton St., Washington, D. C.		
Building, library, operating appliances	206,720.15	
Laboratory apparatus	127,016.18	
Shop equipment	14,025.37	
		347,761.70
Division of Historical Research (Aug. 31, 1930):		
Tower Bldg, Washington, D. C.		
Buildings, grounds, operating	4,235.45	
Library	5,707.11	
		9,942.56

Tortugas Laboratory (September 30, 1930):		
Tortugas, Fla.		
Vessels	$ 30,930.43	
Buildings, docks, furniture and library	12,130.86	
Apparatus and instruments	9,322.55	
		$ 52,383.84
Department of Meridian Astrometry (September 30, 1930):		
Albany, N. Y.		
Apparatus and instruments	4,846.84	
Operating	4,846.55	
		9,693.39
Nutrition Laboratory (September 30, 1930):		
Boston, Mass.		
Building, office and shop	129,289.13	
Laboratory apparatus	34,196.19	
		163,485.32
Mount Wilson Observatory (August 31, 1930):		
Pasadena, Calif.		
Buildings, grounds, road and telephone lines	202,474.64	
Shop equipment	45,421.40	
Instruments	628,366.42	
Furniture and operating appliances	188,811.14	
Hooker 100-inch reflector	601,204.32	
		1,666,277.92
Department of Terrestrial Magnetism (September 30, 1930):		
Broad Branch Road, Washington, D. C.		
Building, site and office	213,267.47	
Vessel and survey equipment	87,950.72	
Instruments, laboratory and shop equipment	135,473.77	
		436,691.96
		3,686,982.82

PUBLICATIONS

Sales of Publications and Value of those on Hand

Table E shows the amounts received from subscriptions to the Index Medicus, from sales of Year Books, and from sales of all other publications for each year since the foundation of the Institution.

E—*Table showing sales of publications*

Year.	Index Medicus.	Year Book	Miscellaneous books.
1903	$2,256.91	$29.25	..
1904	2,370 47	52.85	$12 75
1905	2,562.76	44 75	431.44
1906	2,970.56	37.60	1,341.52
1907	3,676.71	56 50	2,292.89
1908	3,406.19	99.65	4,371 67
1909	4,821.85	73 01	6,287.21
1910	4,470.50	100.70	5,899.05
1911	4,440.21	85.50	6,366.55
1912	4,652.14	61.65	6,782.34
1913	4,992.02	75.95	7,140.69
1914	5,079 16	49.65	6,273.59
1915	5,010.21	47.60	5,239.98
1916	4,382.19	46.60	8,115.37
1917	4,616 21	51.55	7,253.59
1918	4,324.29	21.10	5,575 61
1919	4,267 95	93.30	8,476.33
1920	5,451.86	40 50	12,901.43
1921	6,277.32	50 55	10,356 64
1922	5,774.59	59 25	8,248.00
1923	5,777.46	70 10	7,994.20
1924	4,533 68	31.00	7,429 53
1925	5,636 25	25 00	8,019 49
1926	5,728.31	41 40	8,269.31
1927	1,650.65	59 67	8,322.10
1928	887 85	87 80	9,948 60
1929	433 70	41 74	8,450.47
1930	363.65	127 85	8,977.44
Total	110,815 65	1,662 07	180,777 79

At the end of the fiscal year there are on hand 88,595 volumes of miscellaneous publications and Year Books, having a sale value of $261,943.80, also 1,470 complete volumes of the Index Medicus which together with miscellaneous numbers have a value of $14,994.25.

Growth and Extent of Institution's Publications

The data furnished in table F are of statistical interest in respect to the work of publication of the Institution. 600 volumes, which embrace a total of 176,455 pages of printed matter, have thus far been issued.

F—*Statistics of publications*

Year	Number of volumes issued	Number of octavo pages	Number of quarto pages	Total number of pages
1902	3	46		46
1903	3	1,667		1,667
1904	11	2,843	34	2,877
1905	21	3,783	1,445	5,228
1906	19	3,166	1,288	4,454
1907	38	6,284	3,428	9,712
1908	28	4,843	2,485	7,328
1909	19	3,695	1,212	4,907
1910	29	3,274	4,831	8,105
1911	30	5,062	1,670	6,732
1912	23	3,981	2,044	6,025
1913	29	6,605	2,752	9,357
1914	23	4,978	1,934	6,912
1915	23	4,686	1,466	6,152
1916	35	9,478	2,430	11,908
1917	21	4,464	2,691	7,155
1918	17	3,073	1,120	4,193
1919	29	5,834	2,431	8,265
1920	23	3,962	3,710	7,672
1921	18	4,068	1,398	5,466
1922	24	4,566	2,039	6,605
1923	20	6,459	604	7,063
1924	17	4,665	834	5,499
1925	24	3,970	1,277	5,247
1926	14	4,552	850	5,402
1927	17	4,520	2,089	8,609
1928	15	4,495	1,044	5,539
1929	12	4,938	452	5,390
1930	15	4,096	844	4,940
Total	600	128,053	48,402	176,455

No. 415. **Contributions to Palæontology from Carnegie Institution of Washington. Octavo. Studies of the Pleistocene Palæobotany of California:**

I. Chaney, Ralph W., and Herbert L. Mason—A Pleistocene Flora from Santa Cruz Island, California. Pages 1–24, 7 plates, 1 text-figure.

MISCELLANEOUS

News Service Bulletin:

Colonel and Mrs. Lindbergh Aid Archæologists Pt. I: The Aerial Survey of the Pueblo Region, vol 1, No. 49, 109–114, 1 map, 7 illus.; Pt. II: The Aerial Survey of the Maya Region, by Dr. A. V. Kidder, vol. 1, No. 50, 115-121, 1 map, 7 illus. Notes on Institution Affairs: The 200-inch Reflecting Telescope, 121-122

The *Carnegie* and Her Last Commander, by John A. Fleming and Frank F. Bunker, vol. II, No. 1, 3–9, 8 illus. Notes on Institution Affairs: Institution Bulletin made Available to Schools; Annual Meeting of Institution Trustees, 9–10.

The Artistry of Diatoms, vol II, No 2, 12–16, 8 illus. Notes on Institution Affairs: Report of the 1929 Exhibition Committee, 17–18.

Expedition Returns from Gorilla Sanctuary, vol. II, No. 3, 20–25, 2 maps, 7 illus. Notes on Institution Affairs: The Fifty-Foot Interferometer, 26.

African Rift Valleys—A Geological Study, by Dr Bailey Willis, vol. II, No 4, 28–34, 1 map, 7 illus.

Further Light on the Structure of Matter, vol. II, No. 5, 37–42, 6 illus

Male and Female Bread Moulds, vol. II, No. 6, 45–48, 3 illus. Notes on Institution Affairs: A Cooperative Study of Maya Culture; The Data from Last Cruise of *Carnegie*, 48–50.

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Disclosures of Ancient Life in the Grand Canyon, vol. II, No 9, 64–70, 9 illus.

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REPORT OF THE EXECUTIVE COMMITTEE

REPORT OF THE EXECUTIVE COMMITTEE

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1930.

During this year the Executive Committee held seven meetings, printed reports of which have been mailed to each Trustee.

Upon adjournment of the meeting of the Board of Trustees of December 13, 1929, the members of the Executive Committee met and organized by the election of Mr. Root as Chairman for 1930.

A full statement of the finances and work of the Institution is contained in the report of the President, which has been considered and approved by the Executive Committee, and is submitted herewith. A detailed estimate of expenditures for the succeeding year is also contained in the report of the President, and has been considered by the Executive Committee, which has approved the recommendations of the President in respect thereto and has provisionally approved the budget estimates based thereon and submitted herewith.

The Board of Trustees, at its meeting of December 13, 1929, appointed F. W. Lafrentz & Company to audit the accounts of the Institution for the fiscal year ending October 31, 1930. The report of the Auditor, including a balance-sheet showing assets and liabilities of the Institution on October 31, 1930, is submitted as a part of the report of the Executive Committee.

There is also submitted a statement of receipts and disbursements since the organization of the Institution on January 28, 1902.

The tenure of office of the following officers of the Board of Trustees will expire at the annual meeting on December 12: Mr. Root, Chairman of the Board; Mr. Pritchett, Vice-Chairman of the Board; and Mr. Forbes, Secretary of the Board. The tenure of office of Messrs. Parsons, Paton and Pritchett as members of Executive Committee, of Messrs. Parsons, Pritchett and Wickersham as members of the Finance Committee, and of Messrs. Delano, Parmelee, and Storey as members of the Auditing Committee also expire at the meeting of December 12.

Owing to absence necessitated by reason of his appointment as Ambassador to Japan, Mr. Forbes has submitted his resignation as Secretary of the Board of Trustees.

ELIHU ROOT, *Chairman*
W. CAMERON FORBES
CASS GILBERT
JOHN C. MERRIAM
WM. CHURCH OSBORN
WM. BARCLAY PARSONS
STEWART PATON
HENRY S. PRITCHETT

November 7, 1930.

Aggregate Receipts and Disbursements From Organization, January 28, 1902, to Date

RECEIPTS		DISBURSEMENTS		
Interest from— Securities and Bank Balances	$30,660,373 65	*Investment*	(*)	$44,570,316 24
Colburn Fund	52,015 74	*Pension Fund*		409,357 37
Sales of Publications	293,255 51	*Insurance*		77,079 32
Revertments	514,338 07	*General Contingent Fund*		54,242 64
Pension Fund	42,652 95	*Sp'l. E Reserve Fund*		63,522 48
Insurance Fund	6,963 12	*Grants* Large Minor	 $20,429,934 37 3,836,533 20	24,266,467 57
Redemption and Sale of Bonds	35,738,762 87	*Publication*		1,783,386 90
Carnegie Corp. of N Y	5,906,083 34	*National Research Council*		150,000 00
		Administration		1,528,768 48
				72,903,141 00
Miscellaneous	6,684 96	*Cash in Banks*		317,989 21
	73,221,130 21			73,221,130 21

(*) Including Administration Building, $309,915 69, and Collection Charges.

REPORT OF AUDITORS

WASHINGTON, D. C., *November 25, 1930*

TO THE BOARD OF TRUSTEES,
Carnegie Institution of Washington,
Washington, D. C.

DEAR SIRS:

We have audited the books and accounts of the Carnegie Institution of Washington for the fiscal year ended October 31, 1930. The books of the various departments are audited by the Bursar and Assistant Bursar. We have included their figures in the balance sheet without examination by us.

The income from investments and other sources has been accounted for and disbursements were supported by vouchers.

We counted the cash on hand, and the cash in banks was confirmed by certificates from the depositaries.

The securities representing the investments in the safe deposit box of the Finance Committee were examined by us. The other securities were confirmed to us by correspondence with the Guaranty Trust Company, where they are held in safekeeping.

We certify that the balance sheet, the schedules of securities and real estate and equipment, and the statement of receipts and disbursements as shown in the regular printed financial statement of the Institution at the close of business October 31, 1930, are in accordance with the books, and in our opinion the balance sheet fairly states the financial condition of the Institution at that date.

Respectfully submitted,
F. W. LAFRENTZ & CO.,
Certified Public Accountants.

Copies of the Financial Statement, certified by the auditor in the above report, on pages *62* to *67*.

Balance Sheet, October 31, 1930

Assets

Investments			
Securities ...		$33,368,208.03	
Cash			
Awaiting investment		19,365 01	
Reserved for current needs...		12,025 33	
Property (Harriman Fund)		183,671 75	$33,583,270 12
Property Account			
Real Estate and Equipment at original cost—			
Division of Administration		342,332 60	
Departments of Research..		3,160,978 47	3,503,311.07
Current Assets			
Cash			
In banks	$286,598 87		
Petty cash and stamps	500 00	287,098 87	
Income uncollected for the year 1930. .		234,230 77	
Books on hand at sale price		276,938 05	
Paper in stock for future publications. .		6,413 28	
Outstanding accounts for publications sold...		2,093 48	806,774 45
			37,893,355 64

Liabilities

Endowment and Other Funds			
Endowment		$28,911,608.72	
Colburn Fund		111,666 88	
Reserve Fund		3,165,642 68	
Insurance Fund		510,174 07	
Pension Fund		257,560 21	
Harriman Fund ..		483,671 75	
Special Emergency Reserve Fund . .		137,462 77	
		33,577,787 08	
Increase from Sale and Redemption of Securities (Awaiting Apportionment)		5,483 04	$33,583,270.12
Income Invested in Property ..			3,503,311 07
Current Liabilities			
Large Grants	$266,372 59		
Minor Grants.	64,428 40		
Publications	65,175 09		
Administration.	18,665.92		
General Contingent Fund	52,020 62	466,662 62	
Unappropriated Balance		54,667 02	
Value of Publications, Paper and Invoices		285,444.81	806,774 45
			37,893,355 64

Receipts and Disbursements for Year Ending October 31, 1930

RECEIPTS		
Interest from—		
Securities	$1,637,737 53	
Bank Balances	7,172 13	$1,644,909 66
Sales of Publications		
Index Medicus	363 65	
Year Book	127 85	
Miscellaneous Books	8,977 44	9,468 94
Revertments		
Large Grants—		
Departments	14,998 64	
Contributions—		
American Otological Society	1,900	
National Academy	3,375	
Mrs. C. S Franklin	250	
W J. Salmon	12,130	
Cal Institute Tech	14,106 40	
Eugenic Research Assn	2,000	
D W Morrow	750	
Minor Grants	2,112 29	
Publication	1,054 63	
Administration	1,563 18	
Unappropriated Fund	7,527 24	61 767 38
Pension Fund		14 328 88
Insurance Fund		25
Redemption and Sale of Securities		796,403 75
Carnegie Corp of N Y		1,111,291 67
		3,638,195 28
Balance, Oct. 31, 1929		270,425 69
		3,908,620 97

DISBURSEMENTS		
Investment		
Securities	$1,852,398 85	
Accrued Interest	12,471 81	$1,864,870 66
Pension Fund		51,277 75
Insurance Fund		31,633 43
General Contingent Fund		8,425 61
Special Em Reserve Fund		10 69
Grants		
Large	1,264,258 33	
Minor	183,464 04	1,447,722 37
Publication		
General Publication	81,426 83	
Catalogues, etc	1,353 37	
Shipping expenses	7,287 39	
Division of Publications	23,186 53	113,254 12
Administration		
Trustees	1,401 98	
Executive Committee	3,575 45	
Salaries	48,349 90	
Surety tel & tel	2,559 25	
Printing	2,027 45	
Office expenses	3,117 28	
Equipment	163 55	
Building maintenance	7,581 87	
Lectures and Exhibits	1,840 40	
Option Costs	2,720	
Contingent	100	73,437 13
		3,590,631 76
Cash in Banks		317,989 21
		3,908,620 97

Schedule of Securities

Aggregate—Par or Nominal Value	Description	Maturity	Int. Due	Total Cost or Value at Date Acquired
	Railways			
$500,000	A. T. & S. Fe 1st & ref. 4½s	1962	M-S	$498,750.
43,000	" " " conv. 4s	1955	J-D	39,022.50
50,000	A. T. and S. Fe. gen. 4s	1995	A-O	50,056.25
150,000	B. and O. R. R. gen. and ref. 5s	1995	J-D	153,625.
200,000	Boston & Maine 1st 5s	1967	M-S	195,812.50
100,000	Canadian National Ry. Co. 5s	1969	J-J	98,500.
100,000	Canadian Pac. Col. Trust 4½s	1946	M-S	98,125.
160,000	" " " " 5s	1954	J-D	159,710.07
50,000	Canada So. con. 5s	1962	A-O	49,021.50
175,000	Ches. & Ohio gen. 4½s	1992	M-S	174,062.50
75,000	Ches. and Ohio Ry ref and imp 4½s. Series A	1993	A-O	72,625.
100,000	" " " " " " " " B	1995	J-J	98,250.
100,000	Ches. & O. R. R., Eq. Tr, Series 1929	....	M-N	96,825.50
50,000	Cent. Pac Ry. 1st ref. 4s	1949	F-A	48,250
180,000	Chicago B. & Q. R. R. gen. 4s	1958	M-S	169,501.25
200,000	Chicago B. and Q. Ill. Div. 4s	1949	J-J	200,000.
35,000	Chicago M. St. P. & P 5s	1975	F-A	31,853.50
189,000	Chicago, Ind. & L. 1st & gen. 5s	1966	M-N	189,461 25
140,000	Chicago M. St. P. & P conv adj 5s	2000	A-O	127,414.50
234,000	Chicago M. and St. P. Ry gen 4½s	1989	J-J	227,162 50
120,000	Chicago and N. W. Ry. gen. 3½s	1987	FMAN	100,300.
200,000	Chicago & N. W. R. R. gen. 4¾s	1987	M-N	210,000
300,000	Chicago, R I & P. Ry. 4½s	1952	M-S	282,362 50
100,000	Chicago U. Station 6½s	1963	J-J	114,266 50
100,000	Clev. C. C & St L. Ry., ref. and imp 4½s	1977	J-J	99,272 50
50,000	Clev U Term 1st sink. 5½s.	1972	A-O	51,612 50
375,000	Elgin J & E. Ry. Eq. 5s	.....	J-J	375,000
240,000	" " " 6s	.....	A-O	240,000.
300,000	Erie R. R. gen. 4s	1996	J-J	242,937 50
69,000	Gt Nor. 1st ref. 4¼s	1961	J-J	69,053 25
125,000	Gt Nor. Ry. gen. 4½s	1977	J-J	122,656 25
165,000	" " " " 5s	1973	J-J	174,712 50
300,000	Ill Cent. R. R., Joint 5s.	1963	J-D	311,291 50
121,000	Ill. Cent. R. R ref. 4s	1955	M-N	108,677.50
220,000	Ill Cent. Eq., Trust, 4½s		A-O	211,687.79
400,000	Kan. City Term. 1st 4s	1960	J-J	359,457 50
200,000	Kan City, F. S & M. Ry ref. 4s	1936	A-O	187,250
325,000	Lehigh and L. E 4½s	1957	M-S	331,568.30
100,000	Lehigh V. H. Term. Ry. 1st 5s	1954	F-A	104,750
50,000	Long Island ref. 4s	1949	M-S	48,285
250,000	Louisville & N R. R. 1st & ref 4½s	2003	A-O	249,125
200,000	Mo. Kan. & T. 1st 4s	1990	J-D	165,206 26
213,000	Mo. Pac. R. R. Co. 1st and ref. 5s	1977	M-S	212,762 50
200,000	Mo. Pac. R. R., Eq. Trust 4½s	. .	M-N	192,206 79
150,000	Mobile and O. R. R., ref. and imp. 4½s	1977	M-S	145,750.
55,000	Morris & Essex R. R. Co, Construction Mtg 4½s	1955	M-N	52,987 50
175,000	N. Y. Cent. R. R. ref & imp. 5s	2013	A-O	186,906.25
50,000	N Y. W and Boston 1st 4½s	1946	J-J	49,187.50
70,000	Norfolk & W. Joint 4s	1941	J-D	64,925
100,000	Nor. Pac. ref. and imp 6s	2047	J-J	102,187.50
50,000	" " gen. lien 3s	2047	FMAN	33,101.25
51,000	Ore. Short Line con. 5s	1946	J-J	49,883 25
310,000	Ore. Wash. R. & N. 1st ref. 4s	1961	J-J	274,272.50
80,000	Pa R R. Co. gen. 4½s	1965	J-D	80,900.
125,000	" " con. 4½s	1960	F-A	130,703.13
100,000	Pitts. C. C. & St. L. 5s	1975	A-O	99,637 50
42,000	Pitts Shawmut & Nor. 4s	1952	.....	4,200.
100,000	So. Pac. 1st ref. 4s	1955	J-J	92,148 75
100,000	So Pac. S. F. Ter. 4s	1950	A-O	100,000.
200,000	So. Pac. con. 4½s	1969	M-N	180,000
350,000	So. Rwy. Co. 1st con. 5s	1994	J-J	362,531.25
45,000	St. Paul Union D. 1st & ref. 5s	1972	J-J	48,150.
225,000	St. Louis-S. F., prior lien 4s	1950	J-J	203,431.25
130,000	Term. R. R. Assn. 4s	1953	J-J	114,609.25
210,000	Texas & Pac. R. R., gen. and ref 5s	1977	....	213,882.50
2,084,000	Union R. R. deb. 6s	1946	J-D	2,084,000.
140,000	Union Pac. 1st lien and ref. 4s	2008	M-S	128,722.50
150,000	Union Pac. R. R. 4s	1968	J-D	133,031.25
200,000	Va. Ry. Co. 1st 5s	1962	M-N	206,535.50
200,000	Wabash Ry., ref. and gen. 5s	1976	F-A	203,250.
200,000	Western Md. R. R. 1st 4s	1952	A-O	162,100.
62,000	Wash. Term. Co. 1st 3½s	1945	F-A	53,728.75
13,308,000	Railway Sub-Total	......	....	12,903,182.84

Schedule of Securities—Continued

Aggregate—Par or Nominal Value	Description	Maturity	Int Due	Total Cost or Value at Date Acquired	
	Public Utility				
$200,000	Ala Power Co 1st ref 5s	1951	J-D	$197,250	
100,000	Ala Power Co 1st & ref 5s	1968	M-S	99,656	25
125,000	Am Tel & Tel Co sink deb 5½s	1943	M-N	130,260	62
300,000	Am Tel & Tel Co deb 5s	1960	J-J	308,000	
230,000	" " " " " "	1965	F-A	231,612	50
300,000	Appalachian Electric & Power Co 1st ref 5s	1956	M-N	296,125	
300,000	Ark P & L Co 5s	1956	A-O	292,312	50
250,000	Bell Tel Co of Canada 1st 5s	1955	M-S	257,656	25
100,000	" " " " " "	1957	J-D	101,125	
300,000	Birmingham E Co, 1st ref 4½s	1968	M-S	283,056	25
300,000	Carolina Power & L Co ref 5s	1956	A-O	302,298	75
210,000	Cedar R Mfg & P Co 1st sink 5s	1953	J-J	209,107	04
300,000	Cincinnati Gas & E 1st 4s	1968	A-O	268,105	75
300,000	Columbia Gas and Elec, deb 5s	1952	M-N	303,125	
300,000	Columbus Rwy, P & L 4½s	1957	J-J	285,862	50
40,000	Comm Edison 1st coll 5s	1954	J-D	42,000	
115,000	" " " " 4½s	1956	A-O	114,193	75
65,000	Cons P Co 1st 5s	1952	M-N	67,450	
50,000	Consumers P Co 1st ref 5s	1936	J-J	47,691	
100 000	Detroit Edison gen ref 5s	1955	J-D	99,942	50
150,000	Detroit Edison gen ref 5s	1962	F-A	155,825	
325,000	Ga Power Co 1st ref 5s	1967	M-S	320,112	50
300,000	Gatineau Power, 1st 5s	1956	J-D	298,750	
100,000	Gulf States Util Co 1st 5s	1956	M-S	94,537	50
100,000	Idaho P Co 5s	1947	J-J	100,750	
200 000	Illinois P & L, 1st & ref 5s	1956	J-D	196,750	
200,000	Indianapolis P & L 1st 5s	1957	J-J	198,806	25
200,000	Ind & Mich Elec Corp 1st ref 5s	1955	M-S	202,182	50
300,000	Inter Tel & Tel deb 4½s	1952	J-J	288,250	
280 000	Int Rap Trans ref 5s	1966	J J	276,701	
72 000	Kan City P & L 5s	1952	M-S	71,955	25
45 000	Louisville G & L 1st & ref 5s	1952	M-N	46,456	25
300 000	Memphis P & L 1st & ref 4½s	1978	A-O	279,250	
300 000	Milwaukee E R & L ref & 1st 5s	1961	J-D	302,337	50
100 000	Minn P & L 1st & ref 4½s	1978	M-N	92,156	25
110 000	Narragansett E Co 1st 5s	1957	J-J	109,787	50
52,000	N Eng Tel & Tel 5s	1952	J-D	51,748	
100 000	New Orleans Pub S 5s	1955	J-D	99,200	
50 000	N Y Edison 1st ref 6½s	1941	A-O	55,573	75
42,000	N Y Gas E L H P pur mon 4s	1949	F-A	34,620	50
300,000	New York P & L, 1st 4½s	1967	A-O	286,125	
60,000	Niagara Falls P 1st & con 5s	1959	J-J	61,800	
300,000	Northern Ind Pub S 1st ref 5s	1966	M-N	305,775	
100,000	Northern States P 1st ref 5s	1941	A-O	99,709	50
300 000	Ohio Power Co 1st and ref 4½s	1956	J-D	280,181	25
200 000	Okla G & E 1st 5s	1950	M-S	200,000	
200 000	Pac G & E Co gen & ref 5s	1942	J-J	197,185	53
25 000	Pac Tel & Tel 5s	1952	M-N	26,187	50
50,000	Penn P L 1st & ref 5s	1952	A-O	51,250	
65,000	Penn W & P 1st ref 4½s	1968	M-S	63,212	50
100 000	Peoples G L & C 1st & ref 5s	1976	J-J	102,250	
425 000	Phila L Co 1st & ref 4½s	1967	M-N	427,106	25
100,000	Pub Serv of Nor Ill 1st & ref 5s	1956	A-O	101,975	
150,000	" " E & G 1st & ref 4½s	1967	J-D	150,375	
100 000	" " " " " " " " "	1970	F-A	95,250	
200,000	San Joaquin L & P Corp, ref 5s	1957	J-J	201,968	75
300,000	Shawinigan W & P 1st & coll 4½s	1967	A-O	286,212	50
50,000	So Bell Tel & Tel 1st sink 5s	1941	J-J	47,687	50
300,000	So Calif Edison Co, ref 5s	1952	M-S	307,457	50
50,000	So Calif Tel Co 1st ref sink 5s	1947	M-N	46,000	
200,000	So Pub Util Co 5s	1943	J J	200,000	
100,000	Tenn E & P 1st and ref 5s	1956	J-D	100,912	50
50,000	Texas Electric Service, 5s	1960	J-J	49,250	
250,000	Tex P & L Co, ref. 5s	1956	M-N	246,739	58
165,000	Union Elec Light & Power Co [illegible] s	1967	F-A	164,700	
220 000	Utah L & T Co, ref 5s	1944	A-O	215,193	
300,000	Va E & P Co 1st and ref 5s	1955	A-O	301,606	25
140,000	Washington Water Power Co 1st and gen mtg 5s	1960	J-J	137,550	
12,111 000	Public Utility Sub-Total			11,966,240	52

Schedule of Securities—Continued

Aggregate—Par or Nominal Value	Description	Maturity	Int. Due	Total Cost or Value at Date Acquired
	Mortgages			
$25,000	Empire Title and Guarantee Co., Guaranteed 1st Mortgage, Ctf. No 278 5½%..	1934	M-S	$25,000.
100,000	Lawyers Mtg. Co Guaranteed 1st Mtg. Ctfs., Series 18397 5½%..	1935	J-J	100,000
80,000	Lawyers Title and Guaranty Co., 5½% Mortgage	1935	A-O	80,000
100,000	1st Mortgage 1184 Cromwell Ave., N. Y 5½%	1932	M-S	99,500
100,000	1st Mtg. N W cor Westbury Ct & Flatbush Ave., Brooklyn 5½%.	1933	M-N	100,000.
100,000	Mortgage-Bond Co., of N. Y. 5s	1938	J-D	96,000
90,000	N Y. Title and Mtg Co. Guaranteed 1st Mtg. Ctf , 5%	1938	A-O	90,000
100,000	N. Y. Title & Mtg. Co. 1st 5½s.	1933	J-J	100,000
695,000				690,500.
	Industrial			
200,000	Aluminum Co. of A. 1st sink deb 5s	1952	M-S	201,070 12
50,000	American Radiator Co , deb. 4½s	1947	M-N	49,125
111,000	Genl Motors Acc. Corp sink 6s .	1937	F-A	111,092 09
275,000	Gulf Oil Corp , sink. deb 5s	1947	F-A	278,396 25
15,000	Humble Oil & Ref Co , deb. 5s	1937	A-O	15,000
110,000	Lacka Steel conv 1st 5s	1950	M-S	112,925
110,000	Liggett & Myers 7s ..	1944	A-O	130,058 77
110,000	Lorillard Co 7s. .	1944	A-O	128,614 75
94,000	Midvale S. & O. conv. 5s	1936	M-S	94,205
8,000	Park & T. Co. sink deb. 6s	1936	J-D	6,400
200,000	Rwy. Express Agency, 5s .		M-S	200,000
327,000	Stand Oil N. Y deb. 4½s .			314,926 98
2,129,000	Tenn. C. I & R Co. 5s	1951	J-J	2,129,000
50,000	Tex Corp , Sinking deb 5s .	1944	A-O	49,125
200,000	Youngstown S & Tube 1st sink 5s. .	1978	J-J	200,850
3,989,000	Industrial Sub-Total .			4,020,788 96
	Foreign			
180,500	German External Loan of 1924 7s	1949	A-O	192,840 72
100,000	Govt of Argentina 6s .	1960	M-S	98,250
115,000	Imp Japanese Govt. 5½s	1965	M N	103,212 50
300,000	Kingdom of Denmark, ext 4½s.	1962	A-O	274,375
25,000	City of Montreal 5s .	1956	M-N	24,062 50
75,000	City of Montreal sink. 5s.	1954	M-N	72,375
100,000	City of Montreal 4½s .	1946	F-A	94,368 90
200,000	New South Wales, ext 5s	1958	A-O	189,562 50
100,000	Province of Alberta deb. 4½s .	1958	J-J	93,750
100,000	Province of Alberta 5s.. .	1950	A-O	101.125
100,000	Province of British Col., 4½s	1951	J-J	98,875
100,000	Province of British Col deb 5s	1939	J-J	100,412.67
100,000	Province of British Col. deb. 5s	1954	A-O	99,000.
200,000	Province of Manitoba deb 4½s	1958	A-O	190,515 70
100,000	Province of Nova Scotia 4½s	1952	M-S	100,312 50
100,000	Province of Ontario 4s	1964	M-N	87,150.10
60,000	Province of Ontario 5½s	1937	J-J	61,291.10
100 000	Province of Ontario 5s	1959	M-N	99,789 63
40,000	Province of Ontario 6s	1943	M-S	43,137.50
30,000	Prov of Saskatchewan deb 5s	1943	J-D	30,627.44
75,000	Toronto Harbour Comm. 4½s	1953	M-S	72,062 50
100,000	City of Toronto con deb. 5s .	1949	J-D	96,152.42
90,000	City of Toronto, 5s...	1952	J-D	89,333.53
50,000	City of Winnipeg inter deb. 5s	1943	J-D	48,250.
50,000	City of Winnipeg deb. 6s	1946	A-O	53,500.
100,000	City of Winnipeg deb. 4½s	1946	J-D	95,375.
2,690,500	Foreign Sub-Total... .		. .	2,609,707.21
	Stocks			
50,000	A. T. & S. Fe pref. stock	....	F-A	52,125.
200,000	Cons. Gas. Co. Cum. pref. stock	. .	FMAN	198,725
100,000	Du Pont de Nemours, deb. Stock	. . . .	.....	116,125.
50,000	J I. Case Thresh. M. Co pref stock	.	JAJO	62,225
40,000	Union Pac. R. R., pref stock.		A-O	33,415.
500,000	U. S. Steel Corp., pref. stock	.	FMAN	715,173.50
940,000	Stocks Sub-Total....	. .	.. ..	1,177,788.50
33,733,500	Aggregate—Funds Invested	. .	... ..	33,368,208.03

REPORT OF AUDITORS

Real Estate and Equipment, Original Cost

Administration (October 31, 1930)		
Washington, D. C.		
Building, site, and equipment		$342,332 60
Division of Plant Biology (September 30, 1930)		
Palo Alto, California		
Buildings and ground	$158,044 60	
Laboratory	39,890 47	
Library	16,966 86	
Operating appliances	18,886 14	233,788 07
Department of Embryology (September 30, 1930)		
Baltimore, Maryland		
Library	2,467 63	
Laboratory	11,068 10	
Administration	6,415 53	19,951 26
Department of Genetics (September 30, 1930)		
Cold Spring Harbor, Long Island, N. Y		
Buildings, grounds, field	284,091 73	
Operating	24,018 94	
Laboratory apparatus	17,423 19	
Library	33,651 44	
Archives	45,488 90	*404,674 20
Geophysical Laboratory (September 30, 1930)		
Upton St., Washington, D. C.		
Building, library, operating appliances	206,720 15	
Laboratory apparatus	127,016 18	
Shop equipment	14,025 37	347,761 70
Division of Historical Research (August 30, 1930)		
Tower Building, Washington, D. C.		
Buildings, grounds, operating	4,235 45	
Library	5,707 11	9,942 56
Tortugas Laboratory (September 30, 1930)		
Tortugas, Florida		
Vessels	30,930 43	
Buildings, docks, furniture, and library	12,130 86	
Apparatus and instruments	9,322 55	52,383 84
Department of Meridian Astrometry (September 30, 1930)		
Albany, N. Y.		
Apparatus and instruments	4,846 84	
Operating	4,846 55	9,693 39
Nutrition Laboratory (September 30, 1930)		
Boston, Massachusetts		
Building, office, and shop	129,289 13	
Laboratory apparatus.	34,196 19	163,485 32
Mount Wilson Observatory (August 31, 1930)		
Pasadena, California		
Buildings, grounds, road, and telephone line	202,474 64	
Shop equipment	45,421 40	
Instruments	628,366 42	
Furniture and operating appliances	188,811 14	
Hooker 100-inch reflector	601,204 32	1,666,277 92
Department of Terrestrial Magnetism (September 30, 1930)		
Broad Branch Road, Washington, D. C.		
Building, site, and office...	213,267 47	
Vessel and survey equipment	87,950 72	
Instruments, laboratory, and shop equipment	135,473 77	436,691.96
		3,686,982.82

*Including Harriman Fund property in the amount $183,671.75 shown as a separate item on the Balance Sheet.

REPORTS ON INVESTIGATIONS

DEPARTMENT OF EMBRYOLOGY[1]

GEORGE L STREETER, DIRECTOR

In reviewing the researches with which this Department has been concerned and which have been completed during the past year, it will be seen that many of the studies invade the domains of comparative anatomy. Our ultimate aim is to know more about man and the functional significance of his structure, how this structure is attained and modified, and what are its sources of strength and points of vulnerability. Through embryology we have the obvious approach to the factors underlying these matters, but also much is to be learned through comparative anatomy which in its genetical aspects portrays for us the development and interrelationships of our race. An additional reason for the recent activity in comparative studies is the new mood that has entered the evolutionary field. The time-honored principle of the geneological tree is being subjected to irreverent criticism. Efforts to arrange species on diverging lines from main stems given off by large trunks, beginning with the lower and terminating with the higher, have met with strange complications. Nature apparently can not be reduced to a diagrammatic plane of two dimensions, at any rate if species is to be the unit. The mood now is to regard species as a complex made up of many units and it is among these component units or anatomical characters that the complicated path of evolution is to be traced. The biological universe instead of being represented by a tree will perhaps have to take the form of a galaxy of constellations, in which "higher" and "lower" and branching lines have disappeared. The constellations in turn will consist of clusters and sub-clusters in which the individuals are conglomerates resembling each other in respect to their particular set of component anatomical characters or units. This will introduce some difficulties for the diagram-expert, but apparently it will more closely approximate the truth.

In brief summary, of the investigations having a general embryological bearing there are included in the following report studies of the mammalian egg, dealing with its size, the size of litters, the relation of size of the egg to the individual, and a detailed study of the cleavage of the rabbit egg. Under organogenesis three important stages of the human embryo have been studied and observations have been made on the ossification of the otic capsule, the relation of the tonsil to the branchial pouches, development of the human vagina and of the reptilian sternum. In studying the pathology of the fetus the condition of local gigantism has been investigated. This is of particular interest because of the proof it affords that a given area may make an over-response to growth stimuli. In considering hormones one must therefore take into account not only the stimulant but also the tissue acted upon. Growth becomes the product of the nature of the tissue times the hormonal and other extrinsic growth-stimuli.

In the field of cytology nuclear changes in tumor cells have been studied and an increase in the amount of chromatin in malignant cells has been demonstrated. The behavior of bacteriophage in tissue cultures has been followed and an age factor in grafts has been shown. An interesting study in the metabolism of liver cells has been made, in which for the first time the synthesis of glycogen in tissue cultures has been demonstrated. The secretory function of the kidney glomeruli has been studied in vitro in the absence of blood circulation. With the new motion-picture technique the movements of the various white blood corpuscles and wandering tissue cells have been studied and phenomena have been discovered having a bearing on the functional processes of the cell. In the field of neurology myelinization has been studied in the brain-stem of the 7-month human fetus in correlation with the early functional activities of the nervous system. A study of the highly specialized brain of the porpoise has been inaugurated and a preliminary account prepared of its principal features. The series of studies on the innervation of muscle has been continued and further evidence has been obtained of the absence of control on the part of the sympathetic system. An important review has been prepared of the present status of the problems of cerebral localization. In the field of reproduction a number of studies have originated from our monkey colony where accumulating experience is rapidly widening our knowledge of this important subject. New technique has made possible a closer acquaintance with the changes taking place within the living animals and the phenomena associated with the œstrous cycle and pregnancy can be followed with greater certainty. That there is a definite breeding season has been demonstrated. The nature of various types of uterine bleeding and their correlation in different animals has become more firmly established. Studies have been made on hypophyseal stimulation of the ovary. A study of the gorilla uterus is nearing completion and further investigations relative to the phylogeny of the placenta have been made, with the important conclusion, contrary to the prevailing view, that the diffuse type of placenta of lemurs and ungulates is a highly specialized type and that the primitive type is an invasive placenta. Among studies on the anatomy and physiology of other individual organs there are included the structure of the thyroid gland and its lymphatics, significance of the metopic fontanelle, comparative anatomy of the facial muscles, foot skeleton of man and the large apes, muscles of the primate foot, and skin ridges on the hands and feet of primates. The genetic relationship of monotremes, marsupials and placental mammals have been studied from the standpoint of facial muscles and the cutaneous innervation of the facial region. Finally, there are to be mentioned the important studies on specialization in aquatic mammals.

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[1] Address: Wolfe and Madison Streets, Baltimore, Maryland.

FETAL PATHOLOGY AND ABNORMAL DEVELOPMENT

To understand the pathology of the fetus and the cause of miscarriages it has become apparent that we must look elsewhere than among environmental disturbances such as endometritis, retroversion and physical overexertion. From our experience with human material and from what is known of other animals in which there is a control through plural births it has become apparent that good qualities in the sperm and the ovum are factors of prime importance for normal development.

The egg as a whole develops and lives in proportion to the good qualities with which it was endowed. Good eggs result in hardy, long-lived individuals and poor eggs succumb during uterine life, infancy or the early years of maturity. Similarly the constituent parts of a given egg, and eventually the constituent organs of the individual, are not endowed equally among themselves with good qualities, and they develop and endure in proportion to their respective vitality and degree of vulnerability. That this disparity in quality of the different tissues of the individual is inherent in the germ-plasm is proven by the fact that vulnerable tissues and organ systems are hereditarily transmitted. When this disparity does not extend beyond the usual range it may be considered as normal, but beyond these limits it becomes abnormal or pathological.

LOCAL GIGANTISM

During the past few years I have been studying certain focal defects of the tissues, occurring in the fetus, that are evidently to be explained upon the above grounds. More recently I have had the opportunity of studying a condition that is quite the opposite to focal agenesis or necrosis, namely, local gigantism in which a restricted part of the body makes an excessive response to growth-stimuli.

It is characteristic of agenesis and gigantism to involve sharply delimited areas and this in turn is evidence of the early specificity of the cells that constitute such a part. The particular case of gigantism that I have been studying involves limb-bud material which is known to acquire its specific characters early. In the human embryo as early as the seventh or eighth week, at the time when the digital corrugations appear around the margin of the handplate, the skeleton, muscle masses and the larger nerves are morphologically set apart from each other and can be definitely outlined. But even much earlier than that, as soon as it can be recognized as a discrete surface elevation, the left- and right-sidedness of the limb-bud is established, with all that is thereby involved, that is, if we are to accept the evidence of experiments on lower forms in which the complication of regeneration enters. With the limb-bud thus determined in these early stages it follows that the cells that are to make the index finger, for instance, must be already defined and any inherent abnormality already present. If the cells that are allotted to make the index finger are not normal, an abnormal finger will result. The cells may depart from the normal in various ways, among which four may be mentioned. (1) They may be so defective that they fail to make any finger at all, or only part of a finger if they were not all involved; this is called agenesis. (2) They may be defective in a lesser degree, resulting in a stunted product or one of such material that can not maintain itself. Intra-uterine amputation appears to be of this nature. (3) They may be of a sort that makes a finger of normal size but abnormal in form. Duplicity, polydactyly and syndactyly are common representatives of this type. (4) They may have a surplus of growth capacity and make a finger of twice the normal size. There may be an element of this in polydactyly, but its typical representative is local gigantism, and the latter appears to have its explanation on that basis, rather than any disturbance of the endocrine system. It is to be pointed out that although growth is indeed stimulated through the agency of the internal secretions and other influences it is also regulated by the capability of response on the part of the tissue stimulated. It is the product of the stimulus times the reaction power of the tissue.

ANOMALOUS DEVELOPMENT OF THE LARGE BLOOD-VESSELS

It has been pointed out in previous reports that the vascular system is peculiarly adaptive to the requirements of the environment, and that in the embryo one can demonstrate a continuing change in pattern as the surrounding organs change in size and relative position. At all times one finds the pattern so adjusted as to meet the needs for drainage and supply as they exist at the moment. When the mature arrangement is acquired the pattern remains stationary unless some new complication intervenes. Since in the embryo, the fetus, the infant and the adult, about the same series of requirements exist for each individual, the eventual result in the way of a vascular pattern is approximately uniform. Things, however, are not quite identical and correspondingly one finds variations in the vascular supply. The extent of variation is in proportion to the variation in the functional requirements of the environment. The greatest frequency of variation is out in the capillary bed where the requirements are more poorly defined. So much so that if one can discover some constancy in pattern in such a field he is awarded great distinction. The purposes of the larger vessels are more obvious. At the same time their pattern is more settled and variations in them begin to be notable. Roughly the frequency in their variation is in reverse proportion to their size. The most rare and interesting variations are those of the largest vessels, those at the base of the heart. Two of these have been studied recently here in the Anatomical Laboratory, a left-sided vena cava superior in a negro infant (Dr. B. Halpert and Dr. F. D. Coman) and a right-sided aorta in an adult white male (D. H. Sprong jr. and N. L. Cutler). Of the latter there has been seen only 1 in 223 dissections and they are reported as rare as 1 in 1400. The factors that led to these conditions must have operated very early in embryonic development and are evidently in the nature of growth response in the direction of greatest functional call.

ORGANOGENESIS AND GROWTH

YOUNG HUMAN EMBRYOS

A period of great importance to the embryologist and student of organogenesis is that just preceding and during the laying down of the earlier somites. It is during this period that the main organs are delineated and the embryonic form established. It is on familiarity with this period that we must depend for an understanding of the morphological factors of organformation and the factors underlying variation and abnormal development. In a previous report (Year Book No. 25) an account was given of the investigations of Dr. G. W. Bartelmez and Dr. H. M. Evans on embryos of 2 to 16 pairs of somites. It was a great step forward at the time. Since then from one source or another, new material has made its appearance and more steps forward are being taken. During the past year two additional stages have been completed (Dr. C. M. West and Dr. W. J. Atwell) and descriptions of them have appeared in the Contributions to Embryology. The specimen studied by Dr. West is the 8-somite specimen belonging to the School of Anatomy, Trinity College, Dublin. It is a close companion of the Payne Stage, being but slightly older. By overlapping stages of this kind the continuous story of development will eventually be revealed. The Atwell specimen is a tubal specimen removed at operation by Dr. L. J. Strong of Buffalo and was perfectly preserved. It is a 17-somite stage at which time the anterior neuropore is just about to close and it fills, in a most satisfactory way, a gap that had heretofore been missing. At this period the changes taking place in the brain region attract the major attention, and these are most carefully worked up by Dr. Atwell. In addition he has contributed valuable observations on the nephric, vascular and alimentary systems. In studying the chorda dorsalis he finds that it terminates orally at the prechordal plate, a structure of whose function we know nothing. We may expect that this point will gradually be cleared up, as others have been, by studies such as this one of Dr. Atwell's.

Under this heading mention should be made of an unusually perfect presomite embryo that came to us this last year and is being studied by Dr. C. H. Heuser. It has a germ-disk 1.6 x 0.9 mm. and a yolk sac 1.5 x 1.1 mm. The primitive node of Hensen and notachord extending forward from it could be clearly recognized before sectioning. They were especially clear in a ventral view through a cleft in the yolk sac. The specimen yielded excellent photographic records and has been faultlessly prepared in serial sections under the new Heard-orientation method. Detailed studies of it are now coming through as the first fruits of the improvement in our modelling technique.

Relation of Tonsil to Branchial Pouches

Because of their universal occurrence, great significance has been attached to the series of branchial pouches that form such a prominent characteristic of the vertebrate embryonic pharynx. As with many other pharyngeal structures a dominating influence has been attributed to these pouches in the formation of the tonsil. The tonsil has been supposed to be a transformation of a particular pouch or some portion of it. Whatever may be the significance of the pouches it is becoming apparent that as morphological entities they have nothing whatever to do with the tonsil. Dr. P. M. Levin, in a study carried on jointly in this laboratory and the Anatomical Laboratory of the University of Rochester, has shown that in the pig the branchial pouches come and go, and not until after the permanent topography of the pharynx becomes established do the tonsils make their appearance. The initiation of the tonsil is brought about through a reaction between a specialized area of epithelium and the underlying mesenchyme along with certain cells derived from the blood stream. This area in the pig happens to lie in the soft palate and in the absence of a tonsillar sinus. The crude idea of a branchial pouch being converted in some way into a tonsillar crypt can have no application in the pig. Dr. Levin's observations confirm a similar study made recently by Kingsbury and Rogers in the calf (*Bos taurus*).

Ossification of the Otic Capsule

A movement originating in the American Otological Society toward a better understanding of the cause of progressive deafness and its possible prevention or alleviation has led among other things to a series of researches on the development of the otic capsule. These have been conducted by Dr. T. H. Bast, jointly in this laboratory and in the Department of Anatomy of the University of Wisconsin. Working with serial sections of fetuses of various ages, Dr. Bast has made a microscopical study of the special type of ossification that occurs in the otic capsule and which in its detailed histogenesis presents certain unique features. He finds that there is an intrachondral bone, as he designates it, which is produced by bone cells, lying within the lacunæ of the cartilage islands, surrounding themselves with bone, followed by calcifaction of the cartilage matrix of the islands. By the use of the reconstruction technique he has identified 14 ossification centers and has shown that they arise in relation to nerve terminations, the internal auditory meatus and the semicircular canals. Apparently ossification does not begin at any place until the part of the membranous labyrinth that underlies it has attained its maximum size. In addition to its importance as a contribution to the histogenesis and pathology of bone, Dr. Bast's extensive study will be of much value to the student of the anatomy of the internal ear. His description is made easier to follow by means of carefully planned drawings of his reconstructions.

Development of the Vagina

Owing to the great advance in recent years in our knowledge of the mechanisms of the female genital tract it has become important to explore more deeply into its detailed structure and histogenesis. As will be recalled from former reports, studies have been made toward this end by M. H. Spaulding, K. M. Wilson, J. Shikinami and R. H. Hunter. During the past year the work has been considerably advanced by Dr. A. K. Koff. His attention has been given primarily to the formation of the vaginal primordium and its genetic relation to the urogenital sinus on the one hand and the uterine segment of the müllerian canal on the other.

Dr. Koff finds that the upper two-thirds of the vagina is derived from the müllerian ducts and the lower one-third formed by the proliferation of coalescent elements from the tip of the müllerian cord, the wolffian ducts and the adjacent epithelial wall of the urogenital sinus. The focus of this coalescence constitutes the müllerian tubercle and it is from this point upward that the differentiation progresses. The latter is characterized by an active proliferation of the epithelium with trabecular invasions of the surrounding mesenchyme and subsequent formation of a solid thick mass in which finally a lumen appears through a process of central desquamation. It is this desquamation phenomenon that provides the vaginal outlet into the sinus through the laterally compessed hymenal lips. The histogenetic changes of the vagina are more precocious and more marked at its lower end but changes essentially similar make their way higher up to complete the vaginal canal.

DEVELOPMENT OF THE REPTILIAN STERNUM AND CORACOID

Owing to the circumstance of our having a considerable series of alligator embryos in our collection, the opportunity arose of cooperating with Professor K. Hescheler, of the University of Zurich, in the investigation of the development of the skeletal elements of the shoulder girdle and sternal region. The investigation was carried out by Dr. J. A. Kälin, under Professor Hescheler's direction. Dr. Kälin found that the sternum arises in the form of two sternal bands of condensed mesenchyme which differentiate in a craniocaudal direction. At first the sternal bands are continuous with the coracoids. A complete separation from the latter does not occur until the precartilage stage is reached. The ribs do not share in the original laying down of the sternum but fuse with it subsequently in craniocaudal order. It is to be pointed out, however, that the sternal part of the first rib is laid down near the sternal band and does not seem to grow out from the vertebral part. One would therefore have to say that part of this rib is like the sternum in origin. Careful search failed to reveal any trace of a clavicle.

COMPENSATING VARIABILITY

In his study of fetal growth Dr. Schultz, in the case of some parts of the body which consist of several units, such as the lower extremity, has encountered the possibility of a tendency toward compensating variability, a tendency which would control the variability of the part as a whole. Thus an overgrowth of the thigh might be compensated for by inhibition in growth of the leg and in that way the variability of the total length of the extremity be limited.

Working with Dr. Schultz, Dr. J. Berkson and Miss G. M. Schultz have attempted to determine the extent to which compensation of this kind occurs in the arm and head. Working with about 300 adult males and 200 adult females they made the following measurements: Left arm: upper arm length; forearm, length; and hand length. Head size: head length; head width; and head height. When this data was analyzed it was found that both for the head and the left arm the coefficient of variation is less for the whole than for the individual parts. But it was then found that the same is true whether the forearms and upper arms are from the same individual and biologically related or whether they are taken at random. It was thus evident that other and irrelevant variables were involved. Resort was then had to an analysis based on the apparatus of the partial correlation coefficient. No single one of the partial coefficients proved to be negative in sign when either one or two anatomical parts were held constant. It was therefore concluded that the measurements chosen give no statistical evidence of compensatory variability.

GENERAL EMBRYOLOGY

EMBRYOLOGICAL BASIS OF SIZE

A study in which we have cooperated with Professor W. E. Castle of Harvard University has been made of rabbit eggs obtained from large and small animals. Professor Castle maintains at the Bussey Institution two races of rabbits, one of which has a body weight more than three times as great as that of the smaller race. The birth weights of the two races have a similar relation to each other. It thus became of interest to follow this size-difference back into the prenatal stages and this was done for the pre-implantation period. Four stages were compared varying from 48 to 172 hours after copulation.

Already at 48 hours the eggs obtained from the large race exhibit more rapid cleavage and are likely to be in the thirty-two cell stage, while eggs of the small race are still in the sixteen-cell stage. At 168 hours the blastocysts from the large race are clearly larger in all their measurements than those of the small race. It is clear that there is a more rapid rate of cell multiplication in the large race than in the small race. This results in a larger number of cells in a given time after fertilization and in turn a larger blastodermic vesicle and a germ-disk, or embryo-rudiment, composed of more cells.

Dr. Castle and Dr. P. W. Gregory who participated in the work with him showed by reciprocal crosses that this differential rate of cell division is influenced equally by the spermatozoan and the ovum. This study is in the nature of an exploratory test and is to be followed up as soon as sufficient material can be obtained. The necessary sacrifice of the mother for each supply of eggs makes necessary a large supply of animals. When these are available the individual variation in the eggs, the percentage of abnormal ones, and the differential growth existing between the trophoblastic elements and the embryo proper can be determined. All of these factors must be known if we are to understand the genetic mechanism of size inheritance.

Cleavage in the Rabbit Egg

When the preceding study was undertaken it was found that more precise information than at that time available would have to be obtained regarding the first cleavage stages of the rabbit egg. The factors of shrinkage and distortion that necessarily prevail when eggs are fixed and imbedded for microscopical study were found to invalidate such technique for studies of size-inheritance. It was therefore decided to study and measure the living egg. Dr. Heuser and I had learned much regarding the pig egg from the study of living specimens, and for that reason Dr. P. W. Gregory visited this laboratory to carry out similar studies on the rabbit. The living eggs were kept in a suitable solution at body temperature and photographs obtained at desired moments. In addition a motion-picture record was made, as described in a previous report. For comparison with the living egg, some specimens were prepared as whole mounts, stained to show the mitotic spindles and the relative position of the dividing blastomeres. Other specimens were cut in serial sections and the blastomeres reconstructed by the wax-plate method. This was found advantageous for determining the volume of the individual cells. The results of Dr. Gregory's observations are published in a recent number of the Contributions to Embryology (vol. 21).

It was found that the male and female pronuclei fuse at about 22 hours after coitus and the first division occurs about 30 minutes later. The size of the two primary blastomeres may vary but in the majority of specimens the two are about equal in volume. The second cleavage takes place at about 25 hours and 30 minutes after copulation, and the cleavage spindles are usually, but not always, at right angles to each other. As the blastomeres increase in number the variation in their size increases, which appears to signify a further degree in the segregation of the trophoblastic from the embryonic material. At the 8-cell stage, which lasts approximately from the thirty-second to the fortieth hour after coitus, seven of the blastomeres are arranged so as completely to inclose the eighth. At the 16-cell stage (47 hours after coitus) the mitotic spindles appear to lie in all directions. It is at about this time that one can recognize flattened trophoblast cells on the periphery of the ovum, or morula, which are smaller and further differentiated than the one or two cells that make up the inner cell mass. At about 70 hours the egg passes into the uterus and at the same time a fluid-filled space forms between trophoblast and the inner cell mass constituting the beginning of the segmentation cavity. The latter inaugurates the blastocyst period which is as far as the eggs were followed. Dr. Gregory includes an excellent series of photographs with his published account.

SIZE OF THE MAMMALIAN EGG

Somewhat related to the two preceding investigations is the study of Dr. C. G. Hartman who, working with his own records and with material contained in the literature, has endeavored to determine the range in size of various mammalian eggs. He found that adequate data could only be had from measurements made on living eggs. The shrinkage involved in fixation and sectioning of such material is so extensive and variable that it is unsafe to compare the results of different observers. The mammalian egg is very small, being barely visible to the naked eye, and it has been necessary to develop a special technique for handling and photographing it. Considerable attention has been given to the problem by Dr. Hartman and Dr. Heuser in this laboratory and we are now getting the data necessary for a comparative study of egg-measurements.

The monotremes and marsupials are border-line mammals and possess requirements and characteristics that render them scarcely comparable to other mammals. Dr. Hartman finds that, disregarding them, mammalian eggs do not vary greatly in size, the largest being not quite twice as large as the smallest. Apparently that found in man is one of the largest. The egg in anthropoid apes, dog, goat, pig, horse and whale is in each instance about the same size of that in man. The smallest eggs are found among the rodents, especially the mouse and rat. One could say that the largest mammal, the whale, has about the largest egg, 140 micra in diameter, and the smallest mammal, the mouse, has about the smallest, 70 to 75 micra in diameter. But it is to be added immediately that man with an egg 130 to 140 micra and dog with an egg 135 to 145 micra are equal to the whale, which reduces the significance that might be attributed to relative size.

There appear to be changes in the size of the egg associated with maturation, discharge from the ovary, fertilization and early cleavage. In general, the ovarian egg is larger than the tubal egg up to the time of the formation of the blastocyst. The latter marks the actual beginning of growth. With the improved methods that are now available for the study of living eggs we are in a position to make a series of size determinations for this important period which will throw further light on the physical factors involved in these earliest steps in development.

CYTOLOGY AND STUDIES OF LIVING TISSUES

Nuclear Characteristics of Malignant Cells

In my last report reference was made to the observations of Mrs. M. R. Lewis relative to the increased amount of nuclear material present in malignant cells. Her work at that time was done in collaboration with Miss J. Lockwood and was confined to the study of rat sarcomata, principally Walker tumor No. 1. Since then Mrs. Lewis has continued this study and has extended her observations to tissue cultures and sections of chicken sarcoma, rabbit myxoma, mouse sarcoma, rat sarcomas and carcinomas, and several human tumors.

She finds that all malignant cells exhibit an increase in the amount of chromatin and of nucleolar material. In the malignant cell of some tumors the hypertrophy consists in greatly enlarged plasmosomes, in others there is an increase in number and size of karyosomes as well as hypertrophy of the plasmosomes. Each tumor seems to possess its own characteristic structural pattern, which does not change through many generations of transplantations. Of the different tumors studied there were only two that did not show a marked increase. The malignant cells of these had but a slight increase in chromatin and nucleolar material.

The malignant cells in ten types of tumors were studied by Mrs. Lewis, both in tissue culture and section, with reference to the number of chromosomes. Both normal and malignant cells were found undergoing mitosis. The normal cells invariably appear to have the normal number of chromosomes, whereas the malignant cells may have the normal number, or they may have an increased number, or they may be tetraploid. Among the tumors studied there were some human ones. The malignant cells of some of these had the normal number of chromosomes and some of them had an increased number. One metastatic growth from a breast carcinoma had malignant cells with the tetraploid number of chromosomes. As in the case of nuclear structures in general, the number of chromosomes characteristic of a given tumor remains unchanged through many transplantations in vivo.

Bacteriophage in Tissue Culture

It is known that in test-tube cultures of bacteria there exists under certain conditions a substance or virus that can destroy them, and this substance can be separated from the bacteria and is designated as a bacteriophage. Dr. I. Dresel in collaboration with Mrs. M. R. Lewis has endeavored to learn if such a bacteriophage could attack bacteria within or among living tissue cells without destroying the latter and also whether it would be rendered inactive by the presence of tissue cells. Tissue culture offered a favorable means of determining these points, since the action of the bacteriophage upon the bacteria could be followed from hour to hour and also the behavior of the living cells could be observed in the presence of the bacteriophage. For their investigations they used mouse typhoid bacilli, and a homologous bacteriophage in cultures of susceptible tissue (mouse) and of refractory tissue (chicken).

They first showed that the tissue culture technique does not inactivate the bacteriophage, either when it is in culture alone or in conjunction with mouse typhoid bacilli. They also showed that the potency and stability of the bacteriophage is not injured by the presence of tissue cells in the culture, nor are the tissue cells injured in any perceptible way by the presence of the former. It was then found that in the usual hanging drop tissue culture preparation the bacteriophage (mouse typhoid-phage) shows no lytic action on homologous bacteria (mouse typhoid bacilli) either when the culture is taken from susceptible or from refractory animals. On the other hand, when such cultures were spread on agar plates the bacteriophagic activity could be readily demonstrated. The sites of inoculation developed nude areas or perhaps isolated colonies, whereas when the bacteriophage was not present a well-developed bacterial growth occurred. It now remains to be determined why such substances as plasma, gelatine and white of egg arrest the bacterial lysis of bacteriophage.

Characteristic Movements of Migratory Cells

With the aid of motion-picture photography, Dr. W. H. Lewis has been able to obtain new data relative to migratory and other movements of some of the tissue cells, particularly of the lymphocyte, the polymorphonuclear leucocyte and the macrophage. He finds for each cell-type a characteristic mode of migration. The migration of the lymphocyte is intermittent. From the state of rest, when it is spherical in form, it suddenly darts off, elongating, and moves from one to several minutes, tending to move zig-zag in a given direction. It then stops, becomes spherical again and rests from one to three minutes. The average speed of this "darting-like" progression as calculated from the film is 0.019 mm. per minute; the maximum speed is 0.0348 mm. per minute, at which speed it would require about 30 minutes to travel 1 mm. At this rate it would require 36 days for the lymphocyte to go from one end of the body to the other, providing it retained its maximum speed and met no obstruction. The blood circulation does it better than this. The elongated migrating lymphocyte has an anterior end with pseudopodia, an oval body, and a tail. The anterior end is the only point of attachment and it retains its relative position throughout the period of migration.

The polymorphonuclear migrates continuously, darting about in various directions. Its anterior end tends to shift from one part of the cell to another, contrary to the more stationary polarity of the lymphocyte. Contraction waves pass from the anterior to the posterior end of the cell, often producing a blunt tail.

Macrophages are very changeable in form and move about in an irregular manner by means of large thin, waving, film-like pseudopodia which vary enormously in extent and contour under different conditions. Through the agency of these pseudopodia debris and fluid globules of various sizes are taken up by the cell. The globules can be seen passing from the periphery to the body of the cell, often fusing with each other on the way. As they reach the body they rapidly shrink. Dr. Lewis points out that through this phenomenon relatively enormous amounts of fluid may pass through the cell. These studies are still in progress and are yielding important information regarding the mechanism of cell physiology.

THE AGE FACTOR IN GRAFTS

To what extent the age of transplanted tissue is a factor in its growth and differentiation and in its reaction on the tissues of the host has been studied by Professor Vera Danchakoff, who toward the end of last year was appointed collaborator with this Department. It was known that certain cells of the spleen of the full-grown fowl, when transplanted, differ with respect to phagocytic activity from similar cells of the embryonic spleen. It is also known that there is a difference in the reaction of the host depending on whether the grafted spleen belongs to an adult animal or to an embryo, namely, the adult tissue calls forth an extensive myeloid metaplasia in the mesenchyme of the host, which is not true of embryonic tissue. To determine if similar differences in tissues of different age occur in other classes of animals, Dr. Danchakoff together with Miss V. E. Danchakoff studied grafted spleen in amphibians. Bits of splenic tissue taken from the adult frog and from the tadpole were grafted into the fin of the tadpole tail, which being transparent made it possible to follow the progress of the graft.

It was found that, though very little histological difference exists in the microscopic structure of the spleen of the tadpole and that of the adult frog, there is a marked difference in the fate of the two types of transplant. At the end of six weeks the spleen of the tadpole has disappeared completely. There is left at the site of the graft only a slight condensation of the cellular elements. The grafted splenic tissue of the adult, on the contrary, does not diminish in size, but undergoes an active growth and is found at the end of six weeks studded with mitotic figures.

Also the reaction of the tissues of the host to the presence of the graft is quite different for the two ages. The immediate reaction produced by the adult graft is more acute; there is a marked swarming of polymorphic neutrophile leucocytes from the blood stream which gather around the transplant, giving the appearance of an acute infection. This is a transitory phenomenon and is soon followed by an emigration of small lymphocytes. In the case of the embryonic spleen the reaction is less marked. There is a dilatation of the blood-vessels around it and a slowing up of the blood stream, and small lymphocytes are found crowded against the endothelial walls of the vessels. Following the primary reaction there occurs an emigration of small lymphocytes which infiltrate the transplanted tissue, the latter thereon being cleared of stagnating erythrocytes. This occurs in both tadpole and frog transplants.

There finally follows a recession of cells from the graft into the blood-vessels of the host. Having engulfed the stagnant red cells the phagocytes leave the transplant and accumulate around the blood-vessels and reappear in the lumen. In the case of the embryonic transplant not only phagocytes leave but also other amœboid cells, including small lymphocytes. These pass into the blood-vessels and are transplanted to other parts of the organism. By the end of the third week, due to this emigration of its cells, the transplant has markedly diminished in size, and by the sixth week it has disappeared, leaving only a slight scar of ramified fibroblasts. Dr. Danchakoff regards the emigration of wandering cells from the host's blood-vessels as due to the stimulus of the presence of stagnant erythrocytes. Small lymphocytes migrate toward the graft while they are present and withdraw to the blood-vessels when the erythrocytes have been digested.

In the case of grafts of adult tissue there is a similar migration of phagocytes from the blood-vessels and return. However, the graft does not diminish in size but increases. The cells of the graft proliferate intensely up to the end of the sixth week, when the experiment was concluded. The same lymphocytes already present and those that differentiate from the mesenchymal cells undergo active mitotic division. They remain within the graft and form a definite well-circumscribed lymphatic agglomeration or organ. That these lymphatic cells do not migrate into the blood-vessels must be accounted for by some difference in physico-chemical structure that has come with maturity—a phase of cytology concerning which little is known.

Metabolism in Liver Cells

During the winter and early summer of 1929 the laboratory was fortunate in having as guest Dr. Martin Nordmann, now Privat-Docent in Tübingen, who came to us with experience in the study of metabolism of liver tissue as determined by microscopic study of the living cells. We had already learned that it was possible to obtain satisfactory growths of liver cells in tissue culture, as described in a previous report. Adopting this technique Dr. Nordmann has studied the growth of liver cells and certain phases in their metabolism.

In the first place he found that, although growths could be obtained in Locke-Lewis solutions, much better results were obtained by the addition of plasma, which tended to reduce the number of vacuoles, lengthened the life of the culture and raised the age of the animal from which a successful culture could be obtained. Characteristic outgrowths were thus obtained in the chick and rat in which the liver cells could be clearly identified from other cells by their morphology, staining reaction and epithelial arrangement. It was found that the growth-capacity diminished with increasing age of the animal used for the explant and particularly during the days immediately after birth. This is so marked that one can distinguish from day to day the difference in the age of the donor by the declining growth-rate of the culture obtained from it.

In the metabolism of the liver cell Dr. Nordmann directed his attention particularly to glycogen and fat. He was able to demonstrate for the first time that liver cells under these conditions can contain glycogen and that they synthesize it in the culture. It is retained by the cell in a dissolved state. When the tissues are fixed with alcohol it is precipitated in granular form. Both plasma and the living liver cells can break down the glycogen, and in some cases it appeared that glycogen given off by the liver cells was taken up by macrophages. It is important to note that the presence of glycogen in liver cells is not immediately dependent on the chemical composition of the culture medium. It is formed only during the period when the cultural conditions are favorable and its presence is in direct proportion to the growth-rate of the culture and thus varies according to the age of the culture and the age of the animal from which the explant was obtained. The presence of excessive fat is accompanied by a diminished growth rate and a correspondingly diminished glycogen synthesis. The reciprocal relation between the presence of fat and diminished glycogen formation also exists with respect to diminished growth rate of older cultures. The most favorable reagent for the demonstration of glycogen in tissue cultures was found to be iodin vapor. Its color reaction with glycogen is characteristic and is easily obtained in a reagent glass both with pure glycogen or when it is in solution.

As for fat, which can be readily recognized in tissue cultures, Dr. Nordmann found that, whether it is originally present in the liver cells or stored up in them in the course of the culture, even in large amounts, it does not prevent growth. It does, however, reduce the rate of growth and retards the synthesis of glycogen and thus is correlated with the level of metabolism of the explant and of the liver cells of the culture. His experiments show that if fat is not already present in the liver cells it may be taken up by them from the culture-medium, and due to the lack of its suitable usage it may become stored in considerable quantities.

Finally it is to be noted that Dr. Nordmann's observations on tissue cultures agree with what is known for the living liver tissue in that metabolism in these cells is not so much dependent on the exact composition of the surrounding medium as on its quantitative conditions. In the living animal this is regulated by the blood stream under the control of the nervous system. In cultures the medium is stationary and is only modified by its gradual exhaustion.

Secretory Activity of Glomerular Epithelium of Kidney

Taking advantage of the fact that epithelium and various other types of cells remain alive for many hours after removal from the body, Dr. W. H. Lewis has been able to study the behavior of the glomerular capsules of the kidney under such circumstances. He found that, if small pieces of adult rat kidney are immersed in Locke solution, there will have collected at the end of three hours, large amounts of fluid in the glomerular capsules between Bowman's membrane and the capillary tuft, distending the capsule. Other tissues when treated in this manner show no indication of the collection of fluid. Dr. Lewis therefore concludes that the glomerular epithelium over the capillaries, and perhaps also the parietal layer normally plays an active rôle in the secretion of fluid, rather than merely allowing fluid to filter passively through the cells under vascular pressure. Certainly under the conditions of his experiment there was no vascular pressure, and in fact there was no vascular circulation at all.

It was noticed that not all of the glomeruli were distended with fluid. This is explained by Dr. Lewis by assuming that the convoluted tubules either by their length or due to manipulation obstructed the escape of fluid from the swollen glomeruli, whereas no obstruction existed in the case of the others.

THE NERVOUS SYSTEM

Extent of Medullation of Brain-Stem in the Seventh-Month Fetus

Over a period of several years, Dr. O. R. Langworthy has been studying the sequence of medullation in the developing central nervous system and at the same time correlating the degree of medullation with a physiological study of the behavior of the fetal and newborn animals from which the specimens were obtained. It was found by him in kittens that nerve tracts become medullated in the order in which they have developed phylogenetically and that there is, in general, a relationship between the development of functional activity of the neurone and the appearance of a myelin sheath. Similar correlated physiological and histological studies of pouch-young opossums show that complex activity may be carried out before any tracts in the nervous system are myelinated. The myelin is deposited in the period just preceding the departure of the animals from the pouch to maintain themselves in a more difficult environment.

In extending these studies to human material, Dr. Langworthy is first determining the myelinization of the brain-stem and spinal cord in fetuses of the later months of pregnancy and subsequently the sequence of myelin deposits are to be correlated with the functional activities that exist at the successive ages. In this way one may expect to better understand the order of development of the functional reflex patterns. During the past year Dr. Langworthy has completed the histological study of the brain-stem of the seventh-month human fetus, an account of which has recently been published in the Contributions to Embryology (vol. 21).

A preliminary reference to Dr. Langworthy's study was made in my last report. If one reviews his description in its final form it will be seen that in the seventh-month brain the only medullated fibers found anterior to the midbrain are those of the globus pallidus and a few from the medial lemniscus extending into the thalamus. This is an interesting fact when it is realized that the fetus when prematurely born at this time is viable. The true cranial nerves are all medullated, although the amount of myelin varies. Those heavily stained are the vestibular, oculomotor, trochlear, abducens, hypoglossal (not quite so deeply), motor root of trigeminal, the facial, motor roots of the glassopharyngeal, vagus and accessory nerves. The fibers to the descending nucleus of the trigeminal and the tractus solitarius also stain deeply.

Of the descending paths from the brain-stem to the spinal cord, the vestibulo-spinal, reticulo-spinal, tecto-spinal and the medial longitudinal fasciculus are myelinated. Of the ascending tracts myelinated fibers are found in the spino-cerebellar tracts all the way to the vermis of the cerebellum; spino-thalamic fibers lose their myelin before reaching the thalamus. The cuneate tract can be followed to the nucleus cuneatus, and from this internal arcuate fibers can be followed into the medial lemniscus. As one would expect, the proprioceptive fibers from the upper cord become myelinated before those of the lumbar cord.

Of the cerebellar tracts Dr. Langworthy finds those oldest phylogenetically receive their myelin first (spino-cerebellar, olivo-cerebellar and vestibulo-cerebellar). The corpus restiforme can be traced to the cortex of the vermis. Of the deep cerebellar nuclei, the nuclei of the root, nucleus globosus and nucleus emboliformis give rise to myelinated fibers. The fibers from the emboliform nucleus can be traced through the brachium conjunctivum, but they lose their myelin before reaching the red nucleus. In the olive, as in the cerebellum, myelin is first found on its oldest fibers, *i. e.*, those arising from its mesial portion.

BRAIN OF THE PORPOISE

Several excellent specimens of the brain of the porpoise (*Tursiops truncatus*) were obtained on the expedition to Cape Hatteras, which was referred to in a previous report from this department. These brains are of particular interest because of the highly specialized nature of this marine mammal. They are being studied by Dr. O. R. Langworthy and a preliminary description of them has already been completed.

Dr. Langworthy finds that as in other whales the brain, in conformity to skull, is markedly brachiocephalic. The cerebral hemispheres are large and are highly convoluted, more so than those of man. The cerebellar hemispheres are large and the flocculus is well developed. The cerebral and cerebellar hemispheres are connected by a massive tract of fibers. No olfactory nerve filaments nor olfactory bulbs could be identified and the secondary olfactory end stations are rudimentary. On the other hand the cochlear nerve and its connections with the nervous system are strongly developed.

Microscopic examination of the cerebral cortex reveals a very primitive structure; there are few cells and they are poorly differentiated into cell layers. A large motor area can be recognized at the frontal pole of the brain together with an area frontalis. The motor cortex and the projection areas are surrounded by large areas of undifferentiated cortex. The granular layer is found everywhere except in the motor cortex. The supragranular pyramidal layer is thin throughout the cortex. A detailed study of the acoustic and optic tracts in the porpoise promises to be of particular interest because of the unusual ascendency of its sense of hearing over that of vision.

INNERVATION OF SKELETAL MUSCLE

Continuing her experiments on muscle innervation, Dr. S. S. Tower has endeavored to determine whether or not trophic or degenerative changes occur in muscles that are deprived of their sympathetic nerve supply. It will be remembered that Dr. Tower, Dr. Hines and Dr. Coman have previously demonstrated that muscle tonus is in no way dependent on sympathetic innervation of the muscle. There remained the possibility that the sympathetic nerves might exert some influence of a trophic or nutritional character. To test this point Dr. Tower has studied histologically specimens of muscle from the fore-paw, lower arm and upper arm in a series of adult dogs, cats and goats in which various lengths of the thorico-cervical sympathetic chain had been removed two months to two years before the death of the animal.

The muscle was studied for intensity of staining, clearness of striation, number and size of nuclei, amount and character of connective tissue, and the diameter of one hundred fibers chosen at random in each specimen. In respect to these criteria the muscles deprived of sympathetic innervation were indistinguishable from the normal. Therefore one must conclude that sympathetic innervation of muscle does not exert any visible trophic effect on the muscle fibers. Dr. Tower also studied muscles that were actively growing. In a series of young kittens muscles were deprived of sympathetic innervation during the first ten days of life, and the animals were allowed to survive as long as a year. Careful examination of these animals during life gave no evidence of any difference between the operated and the non-operated sides in respect to growth, activity, muscle bulk, strength, or tone. The microscopic study of this kitten material has not yet been completed.

A study somewhat related to this has been made by Dr. Marion Hines on the extrinsic muscles of the eye in the rabbit. In her experiments she has been able to show that division of the oculomotor nerve at the base of the brain results in degeneration of all the nerves and nerve-endings of the extrinsic eye muscles, excepting those supplying blood-vessels. The latter also degenerate when the cervical ganglionic chain is removed. On the other hand, when the cervical ganglionic chain alone is taken out, the blood-vessels become almost completely denuded of nerves, but none of the four varieties of nerve endings typical for the eye muscles are disturbed. It is evident, therefore, that the latter are all supplied by the oculomotor nerve. Since sympathectomy alone does not always completely denude the blood-vessels of their nerves and nerve-endings, it is probable that some fibers are received by them from the oculomotor, as well as from the cervical sympathetic chain. In these experiments Dr. Hines used the very delicate methylene-blue injection method for distinguishing the different varieties of nerve-endings.

Cerebral Localization

A comprehensive review of the present status of our understanding of the functional nature of the cortical tissues of the brain has been completed by Dr. Marion Hines. Having made important contributions herself to the comparative anatomy and embryology of the brain, Dr. Hines was well equipped for the analysis of the present literature and accumulated anatomical and physiological data. Her review should prove of much value to all those interested in neurology. It will certainly be kept close at hand in this laboratory.

In the brain as in other biological functions we find that the processes are not so simple as was first thought. The diagrammatic sharply circumscribed functional areas have largely disappeared from the cortex. Dr. Hines emphasizes, however, that though there is little if any definite localization in the cortex in the old sense of centers, nevertheless the cortex of man is not equipotential. It is clearly demonstrated that lesions of certain sites produce changes in definite physiological and mental processes and that the depth and breadth of the lesion is of importance. The quadrant projection of the retina upon the occipital lobe comes nearest to conforming to the original concept of localization. The motor cortex, the outstanding *terra cognita,* shows a much greater capacity for variation than was realized. It has an unsuspected wealth of association existing in the stratifications of its layers which appears to explain the variable position of cortical points and such phenomena as facilitation, reversal and deviation of response. Muscular contractions initiated from the cortex have an entirely different quality from those aroused at lower levels. They are more facile and labile and are more capable of modification. As Dr. Langworthy finds to be true in the order of myelinization, so Dr. Hines finds true of the functional development of the cortical regions, that the ontogenetic sequence in the maturation of the various functions in general repeats their phylogenetic history.

ORGANS AND MECHANISM OF REPRODUCTION

Periodic Uterine Bleeding

During the past year Dr. C. G. Hartman has actively prosecuted his studies of uterine bleeding in the *Macacus rhesus*. He has now recorded 18 pregnancies, in all of which a slight bleeding occurs at the time of implantation, the so-called placental sign. From his further study of this phenomenon and from a wide review of placentation in other vertebrate forms he finds homologies between it and menstrual bleeding. He points out that it is the menstruating forms that have a peculiarly hemorrhagic type of implantation. For the two processes, he hypothecates a common cause and predicts that it will be found outside of the ovary, although of course the latter cooperates in the maintenance of the menstrual rhythm and must be admitted as a link in the endocrine chain. Certainly, in view of the fact that periodic menstruation may take place in the monkey in the absence of ovulation, the primary cause must lie outside the graafian follicle.

Dr. Hartman has correlated intermenstrual, or midinterval, bleeding as it occurs in the monkey with related phenomena in man, dog, cow and guinea pig, and his chart is herewith reproduced. It will be seen that he regards the midinterval bleeding of the monkey and man ("mittelschmerz," "faux règles") as homologous to the hemorrhage observed in dog and cow in heat and that it is synchronous with ovulation. Menstruation and the bleeding at the time of implantation belong in an entirely different category.

The Breeding Season in Macacus rhesus

Up to January 1, 1930, there had been 19 pregnancies in the Carnegie monkey colony in which complete records had been made. These have been studied by Dr. Hartman and he has been able to determine more fully the variations in the duration of pregnancy and the fertile period of the menstrual cycle, and has also established the important fact that under the conditions of our colony there is an annual breeding and non-breeding season.

As for the duration of pregnancy there were available 16 cases that had been allowed to terminate spontaneously. In one of these an abortion occurred on the one hundred and twenty-fifth day after mating, and another resulted in a still-birth on the one hundred and fifty-third day. The remaining 14 gestation periods were as follows: 149, 155, 159, 164, 165, 167, 167, 167, 168, 169, 169, 170, 171, 174 days. With the still-birth included, the average for ten multiparæ is 162.5 days; for five primiparæ 169 days; and for all 15 cases 164.3 days. If the extremes are regarded as exceptional it would limit the highly probable period as between the one hundred and sixty-fourth and one hundred and seventieth day. The difference in the duration of their intrauterine residence can be recognized in the appearance of the babies. Those born early are smaller and apparently less mature, *i. e.*, younger, than those born late.

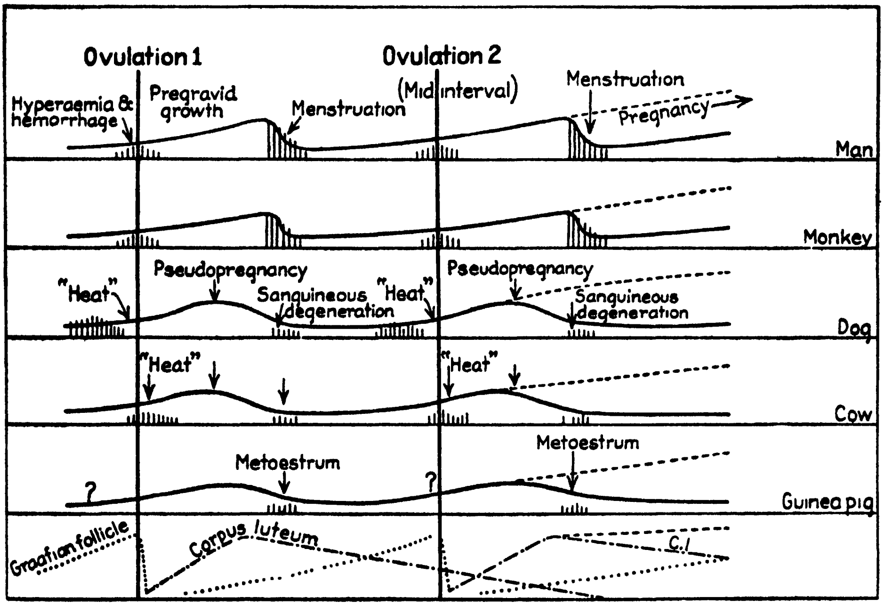

Chart devised by Dr. Hartman showing homologous bleedings in menstruating and non-menstruating animals. The curves show the alternate building up and recession of the endometrium. Correlated in the bottom frame are curves representing the growth and degeneration of the graafian follicle and the corpus luteum

The fertile period of the cycle appears to lie between the ninth and twelfth day following the beginning of the last menstruation. Of sixteen pregnancies, the fertile coitus took place within this period. In three others one was mated eighth to twelfth day, one mated eleventh to fifteenth day, and one mated the ninth to eleventh day. The average of the days involved is 11, and Dr. Hartman regards the eleventh as the most fertile day of the cycle. Of the many matings made outside of this period none was effective, though the animals copulate at all times. There thus appears to be a definitely sterile part of the cycle in the monkey, which does not seem to be true for man.

In addition to having a restricted fertile period in the menstrual cycle, Dr. Hartman finds that in the *rhesus* monkey there is an annual breeding and non-breeding season. Of 19 pregnancies, conception occurred in 15 of them within the month of November, which in our colony appears to be the optimum time for the initiation of pregnancy. The summer months, on the other hand, constitute a non-breeding season. The full list of conceptions occurring in different months is as follows: September, 1; October, 2; November, 7; December, 4; January, 2; March, 2; April, 1.

Twelve laparotomies were done in June and July on animals that had ovulated during the winter and the ovaries were found to be devoid of follicles or corpora lutea, except in one case in which there was an atretic follicle. During this period of æstival ovarian rest, menstruation may continue with perfect regularity, though it does not always do this.

METHODS OF FOLLOWING THE SEXUAL CYCLE IN MONKEYS

Vast progress has been made in recent years in our knowledge of the physiology of reproduction, and the individual advances have come largely through the device of new techniques and tests for determining the processes that are transpiring within the living animal and that can be followed from day to day. Dr. Hartman's success in the management of a breeding colony of macaque monkeys could scarcely have been attained had he not developed a system of vaginal washings which enabled him to determine easily and precisely the character of the secretions of the genital tract of the individual animals, with a technique that could be carried out daily, and for a considerable number of animals.

During the past year still further information has become available through bimanual rectal palpation, and it is now possible with great ease to palpate the uterus and both ovaries. With this method, Dr. Hartman has been able to follow the changes in the size and consistency of the uterus throughout the cycle. In an ovulatory cycle there is a premenstrual enlargement and softening of the uterus with a characteristic change in shape and size of the ovaries. In pregnancy there is an initial softening of the entire uterus, so that it feels like a well-developed premenstrual organ. Later the lower segment and cervix become so yielding to touch that they can be scarcely felt, whereas the fundus with the contained ovum remains firm. Midway through pregnancy or shortly thereafter the vagina also begins to enlarge and soften. A detailed study of these changes is now being made in pregnant and non-pregnant animals.

SIZE OF EGG-LITTERS

In a study of excessively large litters of eggs liberated at a single ovulation in mammals, Dr. C. G. Hartman correlates the phenomenon with hyperactivity of the anterior lobe of the hypophysis. The ovaries in the female mammal initially contain an enormous excess of oöcytes beyond the reproductive needs of the individual, and the number that are destined to mature and become discharged as free ova in the oviduct ready for fertilization is regulated by a hormone that is now known to be supplied by the hypophysis. In so far as this endocrine function is constant for a given species of animal, the number of eggs shed by that animal, or litter size, will be constant within rather definite limits.

The number of eggs ovulated and the number of young successfully born differ to the extent of lack of fertilization and prenatal death, the average loss being about one-third of all the eggs shed. This phase as it deals with fecundity has been referred to in previous reports. With this in mind it will be seen that, in common with certain other marsupials, the opossum, which was studied by Dr. Hartman, far surpasses all other mammals in reproductive capacity. The great majority of mammals produce 4 or fewer young at one time. The more prolific species run up to 12 or even 16. Exceptionally large litters may occasionally occur, the maxima appearing to be the following: pig, 24; dog, 22; rat, 22; rabbit, 18, and man, 6. Compared even with these abnormal cases the observations of Dr. Hartman on the opossum show that it is much more prolific than its higher mammalian relatives. Evidently in the opossum 18 to 20 pouch young is not exceptional. In 12 animals which were examined 5 were found to have 30 to 36 eggs, 6 had 39 to 45 eggs, and one yielded 56 eggs. As an exceptional case, associated with abnormal uterus and ovaries, one animal was observed that discharged 60 eggs at one ovulation. The normal range of the number of eggs ovulated by the opossum would, however, appear to fall in the thirties or forties.

HYPOPHYSEAL STIMULATION OF THE OVARY OF THE MONKEY

In the preceding paragraph mention was made of the hormonal regulation of egg production. An experimental demonstration of this has been obtained in the *Macacus rhesus* monkey by Dr. C. G. Hartman. An adult animal that had had a series of menstrual bleedings apparently unaccompanied by ovulation was examined by laparotomy, and the ovaries and uterus were found to be of minimal size for her age and there was no sign of recent ovarian activity. The anterior lobes of the hypophyses of two adult castrated pigs were introduced retroperitoneally at the time of the operation. On each of three successive days thereafter two additional glands of the same kind were implanted in her rectus muscle. Four days after the last implant the vaginal fluid contained red blood cells and had the appearance of intermenstrual bleeding which in the monkey seems to be the counterpart of prosestrum in the dog. Two days later, nine days subsequent to the first implantation, the animal was again opened for inspection of the organs in the living state. The ovaries were found to be much enlarged with their entire surface studded with graafian follicles 3 to 4 mm. in diameter, distended with clear liquor folliculi. The uterus was also much enlarged and vascular. The ovaries were removed and were found to measure 13 x 12 x 10 and 14 x 12 x 10 mm., which is the largest we have ever seen in any *rhesus* female in our colony. The increase in size of the ovaries was found to be due to the growth of numerous graafian follicles. This stimulation of the ovaries and uterus was accompanied by a proliferation of the mammary glands.

The complete success of this experiment is in part due to the fact that the hypophyseal tissue was crushed at the time of implantation. A previous similar experiment with another animal had been made, in which the glands were implanted whole and intact. In that case ovaries that were absolutely devoid of visible follicles and corpora lutea were stimulated to the production of follicles of pin-head or mustard-seed size. The experiment revealed a positive effect of the implanted gland but was not so striking as when the gland tissue was crushed.

PHYLOGENY OF THE PLACENTA

Two years ago I reported the observations of Dr. G. B. Wislocki made on the placenta of *Hyrax,* which animal possesses a significant primitive type of implantation. Since then he has obtained another stage of this rare material which with his previous specimen seems to reveal the true nature of implantation in *Hyrax* and harmonizes the seemingly irreconcilable observations of previous investigators.

Dr. Wislocki finds that in the development and definite structure of its placenta, *Hyrax* is unlike any other order of mammals. In its gross form its placenta bears a resemblance to that of the carnivores, but it is fundamentally different in its structure and in the small rôle played in the implantation by the uterine glands. It also resembles the placentation seen in insectivores and rodents, particularly in respect to the marked growth of trophoblast and the delayed invasion of the trophoblast by the chorionic mesoderm, or, perhaps more correctly expressed, the delayed differentiation of the trophoblastic stroma. *Hyrax* implantation, in its placental labyrinth and in its trophoblast and stromal elements, resembles most of all *Tarsius*. On the other hand, it bears no resemblance at all to the diffuse type of implantation characteristic of the ungulates to which it is in other respects so closely related. Dr. Wislocki concludes that the diffuse type of placenta in the lemurs and ungulates is derived secondarily from the more primitive deciduate type, such as is seen in *Hyrax* and *Tarsius*. The ungulates and lemurs, possessing a diffuse placenta, are highly specialized, extremely divergent groups. On the other hand, the more archaic or main-line mammals almost uniformly possess the burrowing type of placenta, such as *Hyrax, Tarsius,* some marsupials, the xenarthras, carnivores and insectivores. It is suggested by Dr. Wislocki that the sluggish differentiation of mesoblast as seen in *Hyrax* may be an expression of the factor that ultimately produced the diffuse placenta. He argues that trophoblast insufficiently vascularized would be subject to arrested proliferation and perhaps to atrophy of its deeper portions. There would be the tendency in such a placenta to develop only in its superficial parts and become diffuse in its contacts with the endometrium. This particular reasoning is doubtless ventured by him in order to appease those who relish speculation. However, there is certainly no evidence for what has been the prevailing view, that the present-day diffuse placenta of lemurs and ungulates was derived uninterruptedly from a hypothetical primitive diffuse placenta. On the contrary, the admittedly primitive mammals possess invasive placentæ.

The allantoic sac is unusual in *Hyrax,* in that it does not fuse with the chorion to produce an allanto-chorion, but fails to unite, thereby leaving an extensive space between the two membranes. In addition to this the allantois is avascular, except for its four-horned pedicle which serves solely to conduct the umbilical arteries to the chorion. Here again *Hyrax* differs widely from the remaining ungulates in which the allantois is completely vascularized and forms an allanto-chorion. Dr. Wislocki points out that if *Hyrax* is more primitive, then the non-vascular allantois and direct vascularization of the chorion may be a more primitive condition than a completely vascularized allanto-chorion.

Female Reproductive Tract of Gorilla

The genital tracts of three adult female gorillas have been studied by Dr. G. B. Wislocki, and a preliminary account of them has been published in which they are compared with equivalent reproductive tracts of man, other anthropoid apes and monkeys. When compared from the standpoints of the external genitalia, internal genitalia and placentation, in all of these aspects the three great apes—gorilla, chimpanzee and orang-utan—show close relationships. Man and the gibbon show marked dissimilarities from them, though they are nearer to the great apes than they are to the catarrhine or platyrrhine monkeys. The external genitalia of man are unlike those of the apes or catarrhines and resemble those of the primitive platyrrhine monkeys. The internal genitalia of man, however, resemble very closely those of the gorilla, chimpanzee and orang-utan, and as for implantation the indentity is almost complete. The gibbon in its different characters shows affinities to the great apes as well as to man and the catarrhine monkeys.

The similarity of the human reproductive tract to that of the gibbon would indicate that man is related as intimately to the most primitive of the anthropoid apes as to any of the others. This fact, as well as man's isolation in reference to external genitalia, are regarded by Dr. Wislocki as indicating that man's phylogenetic bonds with the existing apes are more remote than is usually assumed. Dr. Wislocki has in preparation a complete monographic account of the gorilla uterus.

ANATOMY AND PHYSIOLOGY OF THE ADULT

The Thyroid Gland

An investigation concerning the structure of the thyroid gland, based on improved methods of observation, has now been published in its complete form by Dr. W. F. Rienhoff jr. In a former report (Year Book No. 27) I described the character of his study and outlined its principal results. Its final publication in the Contributions to Embryology makes available to the anatomist an adequate treatise on the configuration of this important endocrine gland and the ultimate anatomy of its follicles. Dr. Rienhoff has recently extended his observations on the thyroid to the study of its lymphatic system which had been poorly understood. His contribution in this direction is due to his success in obtaining excellent double injections of the gland in the dog; the lymphatic vessels with diluted india ink, and the blood-vessels with Prussian blue. When such specimens are cleared the vascular pattern is revealed with great completeness. Similar injections were also obtained in human material, the specimens being prepared at the operating table and at autopsies.

The thyroid lymphatics were found by Dr. Rienhoff to arise in an anastomosing plexus lying in the spaces between the follicles. This interfollicular plexus is a closed lymphatic system consisting of dilated endothelial sacs, or bursettes, and interconnecting unbranched lymph capillaries. The bursettes and their communicating lymph capillaries drain groups of follicles rather than individual ones. They belong to the spaces rather than the follicles. They are separated from the latter by an intervening blood-capillary plexus, which closely ensheaths the individual follicles.

The interfollicular lymph plexus drains into the general intraglandular lymphatic reticulum and anastomoses with the perivascular plexus. Principally through the latter means, the lymph drainage reaches the lymphatic plexus on the surface of the gland, and from it the main collecting ducts originate.

RESORPTION THROUGH THE GALL-BLADDER

A contribution has been made toward the solution of the much disputed question as to whether the gall-bladder is simply a receptacle and concentrator of the bile, evacuating its contents on appropriate stimulation—or whether it does not in addition act as a resorption mechanism. As noted in these reports, Dr. Halpert has supported the latter view and more recently Dr. W. L. Winkenwerder has been able to demonstrate in the cat that crystalloid solutions (potassium ferrocyanide and ferric ammonium citrate) pass through the epithelium of the entire extra-hepatic biliary system. The cells at a given functional phase, at the end of secretion, show greatly augmented permeability to such solutions. He finds that following its passage through the epithelial cells the solution is returned to the general circulation through the blood vascular system rather than through the lymphatics.

The completed account of Dr. Winkenwerder's study has been published and in it he gives a detailed histological description of resorption by the biliary tract and the cytological evidences of permeability of the cystic epithelium according to its functional states. From his observations it becomes evident that in future studies of resorption by the gall-bladder it will be necessary to use proper control for the exclusion of cell-injury. Such injuries might lead to absorption of substances that would not occur under the conditions of a normal mucous membrane.

SIGNIFICANCE OF THE METOPIC FONTANELLE

Twelve years ago Dr. A. H. Schultz published from this laboratory a paper on the persistence of the metopic suture and fontanelle, which in rare instances occur in the human skull. In those cases the two frontal bones instead of completely fusing in the midline show in the fore-head region a partially persisting suture, or fissure, or even a wide fontanelle. Since that time more material has been collected and during the past year he has reviewed the whole problem and has published his further observations and conclusions.

He finds that the frontal arm of the great fontanelle remains open in 15 out of 100 skulls to the time of birth and into early infancy. Usually by that time it has become partially closed in its upper part so that the metopic and the main portion of the great fontanelle are separated. Similar metopic residues of the great fontanelle are found in newborns and infants of many different animals. Dr. Schultz shows that to this extent they are a normal fetal character, and are neither a regression to ancestral conditions nor a progressive tendency. Their persistence after infancy he explains as a localized retardation in the closure of that part of the great fontanelle and is associated with persisting metopic sutures. It is interesting to note that the metopic fissure and metopic suture show a marked tendency during postnatal growth to increase the width of frontal bones, particularly the width of the interorbital region. They, however, are not correlated with the amount of cranial capacity and can no longer be explained as due to increased intracranial pressure.

STUDIES IN COMPARATIVE ANATOMY

FACIAL MUSCLES

An instructive chapter in comparative anatomy has been contributed by Dr. E. Huber, who during the past year has brought together in an analytical way his extensive studies on facial musculature and their correlation with data obtained from neuro-physiological investigations on the cutaneous field of the trigeminal nerve. First he traces the evolution of this muscle system from lower vertebrates to mammals in which he finds a special ground plan for the monotremes and a common ground plan for the marsupials and placentals. In this he takes account both of their embryological development and their comparative anatomy and phylogeny. He then correlates the development of the motor nucleus of the facial nerve with the expansion and differentiation of the superficial facial musculature. He then reviews his observations on the localization of the facial field within the motor area of the cerebral cortex in monotremes, marsupials and placentals, some of which work has been referred to in previous reports. Dr. Huber then follows the decline of the sensory facial field in the ascending scale of vertebrates to the vestigial cutaneous area left in mammals. Simultaneously there is a rise of the cutaneous field of the trigeminal nerve in mammals. He also describes the evolution of a cutaneous field of the trigeminal nerve in monotremes providing a high sensitivity of the snout. Further phases of these studies are to be added. His present review concludes with an account of the acquisition and elaboration of the tactile facial vibrissæ in the marsupials and placentals, and the part they play in the evolution of the superficial facial musculature, the cutaneous field of the trigeminal nerve and of the neopallium. Dr. Huber's important studies could hardly have been carried out had he not been exceptionally gifted in the art of graphically recording his dissections.

Recently Dr. Huber has entered more in detail in some phases of the comparative anatomy of the facial muscles and finds that their arrangement in monotremes differs fundamentally in their ground plan from that of the marsupio-placentals, which he explains as divergent specializations associated with the elongation of the snout in Echidna and the formation of a bill and acquisition of a buccal pouch in Ornithorhynchus. In both of these there is a massive platysma which extends backward to interlace and partially fuse with the panniculus carnosus. Strong portions of it insert into the forelimb, while the remainder passes below the ear into the face where it is firmly attached to the base of the rigid snout. Facial muscles are grouped around the ears and eyes. Both of the monotremes have a powerful sphincter colli and in both of them the external sphincter extends forward to the base of the snout. There is an absence, however, of a continuous deep sphincter.

Dr. Huber has extended his studies of the facial musculature to the problem of racial variations in facial expression. He finds that though these differences are largely associated with varying psychological reactions they are also due to structural differences in the facial musculature along with differences in the skin and subcutaneous tissue. Racial characteristics appear to be more conspicuous in the facial musculature than in the rest of the muscle system and the differences appear early in fetal life. The material on which Dr. Huber's observations are based consists of a large series of American negroes (fetuses, newborns, children and adults) which were compared with similar stages of white specimens and an adult Chinese.

GENETIC RELATIONSHIP OF MONOTREMES, MARSUPIALS AND PLACENTAL MAMMALS

In studying the facial region of monotremes, Dr. Huber finds that in the phylum the cutaneous branches of the trigeminal nerve show an arrangement that is fundamentally different from that of marsupials and placentals. These trigeminal branches emerge through a series of foramina in the nasal, maxillary, and at the junction of the maxillary with the premaxillary bones, and at various points on the inner and outer surface of the mandibles. From these multiple outlets they concentrate on the naked snout which is thus supplied with abundant innervation. The trigeminal branches are much larger in the Ornithorhynchus, which is largely guided by the tactile sense of the snout, than in the Echidna in which the olfactory sense is the dominating one. Contrasted to those of the monotremes the cutaneous branches of the trigeminal nerve in marsupials and placentals bear relation to the facial tactile vibrissæ which are not present in the monotremes, though present in all other mammals.

Due to the striking peculiarities of the facial musculature of the monotremes and the singular pattern of the cutaneous branches of their trigeminal nerve, together with a whole series of further characteristics, in which the monotremes differ fundamentally from the rest of the mammals, Dr. Huber concludes that the monotremes must have had an individual derivation, apart from the marsupials and placentals; they must have arisen from a different group of the theriodont reptilian stock. On the other hand, the common ground plan that characterizes marsupials and placentals in respect to their facial musculature, the restriction of the tactile surface of the snout to the rhinarium, the possession of facial tactile vibrissæ; the distribution of the cutaneous branches of the trigeminal nerve, and the arrangement of the foramina through which these branches emerge from the skull, is evidently to be attributed to the common ancestry of these two phyla.

GROWTH AND DENTITION IN THE ANTHROPOIDS

Much progress has been made in recent years toward a closer acquaintance with the structural details and growth changes in the anthropoid apes, due in part to the increased importance that the problem has assumed, and in part to the increase in material that has become available. The latter item is still far from having reached a desirable goal, but through the generous cooperation of some of our larger museums and zoological gardens Dr. Schultz has been able to assemble enough data to give a rough outline for the weight and measurements of the orang, chimpanzee and gorilla at representative ages and for the two sexes. In all there were 23 specimens. Some were preserved bodies, others were living and some of the living ones were measured repeatedly. This of course is scant material but it is the best to be had at present, and it provides a provisional growth curve for these three anthropoids.

As for the eruption of deciduous teeth, Dr. Schultz finds that, as in man, the time and sequence of eruption in the apes varies individually very much. But the milk teeth seem to appear in much more rapid succession in apes than in man, namely, between the four and one-half to the twelfth or sixteenth month in apes and between the sixth to the twentieth or thirtieth month in men. The first permanent molars erupt in apes between the ages of 1½ and 3½ years, whereas in man it is usually not before the sixth year. Where it becomes necessary to estimate the age of an ape, the variability in the time of their eruption may make the teeth an unsatisfactory guide. Here one must resort to weight, sitting height and other body measurements. For this purpose Dr. Schultz's tables even with their fragmentary character will prove of great value.

Foot Skeleton of Man and the Large Apes

In a comparative study of the foot skeleton, Dr. A. H. Schultz finds as the most striking peculiarity of the human foot the extreme shortening of the second to fifth toes and particularly the middle phalanges. Of the anthropoids, the mountain gorilla approaches most nearly to man, and the orang is farthest removed. The hallux of the gorilla is even longer, in relation to the tarsus, than that of man. Furthermore the joint for the hallux on the cuneiform of negroes is frequently convex and points toward the side, rather than forward, differing from the same joint in the mountain gorilla only in degree. This study of Dr. Schultz, which has only been reported in its preliminary form, is providing a part of the necessary basis for the understanding of the structural and behavioristic relationships of man and the other primates.

Muscles of the Primate Foot

The deep foot musculature of the primates has been studied by Dr. W. L. Straus jr., particularly with reference to the interosseus and contrahentes muscles and their correlation with the shifting of the interosseus axis. He finds that monkeys possess the typical mammalian arrangement with four contrahentes muscles adducting the toes to an axis through the middle toe. In many prosimians in which the axis is shifted to the fourth toe, the fourth contrahens is missing. Further reduction occurs of the three lateral contrahentes in the gibbon; it is more advanced in chimpanzee and practically complete in orang, gorilla and man. This is correlated with the shifting of the interosseous axis from the third to second toe, which occurs in all men, most gorillas and occasionally in the other anthropoids.

In another group of foot muscles, the perforated and the perforating flexor muscles and the quadratus plantæ, which is closely associated with them, Dr. Straus finds that the anthropoid-ape arrangement is not ancestral to the human condition. The quadratus plantæ is almost constantly present in monkeys, arising by a single head. It seems to be lost entirely in prosimians and gibbons, most gorillas and orangs, and in many chimpanzees. In man, on the contrary, it is rarely absent and has developed a second head, in this respect man being nearer to the monkeys than to the anthropoids. The perforated flexor (flexor digitorum brevis) has a tendency among primates to transfer its origin from the flexor tibialis tendon to the plantar aponeurosis and calcaneus. This transferal reaches its greatest completeness in man, with the orang closely approaching it. Dr. Straus, however, finds himself unable to determine genetic relationship on the basis of the degrees of transference. This is also true for the perforating flexors in which man and gibbon exhibit a more primitive condition than the other anthropoids.

In studying the interosseus muscles of the primate hand and their orientation axis, Dr. Straus finds the length of the digit is an important factor, the axis ordinarily appearing to pass through the longest digit. The primitive condition is an orientation in both extremities with reference to the middle digit, which is the longest one. This is the arrangement in all of the monkeys. In gibbon, orang and chimpanzee the axis is always through the third finger and usually the third toe, occasionally the second. In the gorilla it is through the third finger and occasionally the third toe, but usually the second. In man it is through the third finger and the second toe; it may, however, pass through the second finger, which is occasionally lengthened relative to the third. Dr. Straus thus shows that in the specialization of the hand and foot of a particular genus the two tend to parallel one another in axial shift, and as they do this the foot tends to be more advanced than the hand.

Dermatoglyphics in Primates

The relationship of man among the primates has been analyzed from another and very specialized characteristic, namely, the skin ridges of the palms and soles. This study was made by Dr. C. Midlo, who has been a guest in Dr. Schultz's laboratory during the past year. In my last report reference was made to the closely related study of Dr. Cummins, with whom Dr. Midlo is associated at Tulane University. In the present study it is found that the greatest stability of dermatoglyphic features occurs in the gibbon, and Dr. Midlo explains this on the basis of the extreme specialization of this form. The collective dermatoglyphic variability then increases in the following order: platyrrhines, lower catarrhines, macaque, man and anthropoids. In general, the New World monkeys have deviated least from the fundamental plan, in respect to ridge alignment, placement of triradii and pattern forms. In similar respects, if one overlooks certain specializations, the palmar and plantar markings in man conform more nearly to the fundamental plan than do those in the gibbon and other anthropoids. The Old World monkeys, along with the hypertrophy of their volar pads, show a marked expansion of patterns and also the retention of the primitive whorl pattern. Dr. Midlo is now preparing his observations for final publication.

Specialization in Aquatic Mammals

An important study of adaptation of body structure to functional requirements has been made by Mr. A. Brazier Howell, now Lecturer in the Department of Anatomy of the Johns Hopkins University. In concentrating his attention on aquatic mammals, this investigator has selected a field in which the phenomenon is brilliantly represented. Nowhere is there to be seen a more astonishing evolution of bodily details than has taken place in the whale in the course of its adaptation from an atmospheric to a completely aquatic environment. All aquatic mammals are included in his study and much of the material presented is based on his own drawings and observations. Particular attention is devoted to the mechanics of swimming and a full description is given of the muscular and skeletal adaptation to the different types of this function. In his morphological interpretations, Mr. Howell finds himself subscribing to the principle of inheritance very gradually modified by the use or disuse of parts, and involving hundreds of thousands of generations. The greater part of his study deals with the structural characteristics of these animals and a philosophical discussion of their significance. He supplements these matters, moreover, with a discussion of some of the physiological specializations that are found so highly developed in the Cetacea. Among these are the respiratory and circulatory systems, specialization in the fatty tissues, the digestive functions, and the uro-genital tract and mammæ.

During the past year Mr. Howell's descriptive account and classification of the large collection of Chinese mammals in the United States National Museum has come from the press. It was prepared by him during his period of collaboration at the Museum. It is a treatise that should prove of great value to the student of comparative anatomy and particularly to those who are confronted with isolated representatives of Asiatic material.

DEPARTMENT OF GENETICS[1]

C. B. DAVENPORT, DIRECTOR

GENERAL STATEMENT

The field of genetics, as cultivated in this Department, includes the subject of mutation, or heritable variation. At the beginning of the century, while heritable variation was recognized as a fact, we had little precise notion of the mechanism that lay back of it, or of its essential nature; and this despite the fact that the theory of determiners, or genes, as agents of heredity, is three quarters of a century old. Gradually, our knowledge of the genes has become more precise; their relation to the chromosomes is established; they have, apparently, been seen. These genes guide the processes of differential metabolism upon which development depends.

These genes undergo in some cases at least a series of regular mutations in the course of development, so that they play different rôles at different stages of development. This fact of somatic mutation suggests that the control of differentiation during development, one of the least known of developmental processes, may be the regular, orderly change in the genes as development proceeds.

The nature of gene-change, the causes that initiate it, are still far from being fully known. Certain it is that the nature of the change is controlled largely by the nature of the gene-stuff. Any agent that we apply has its effect determined largely by the specific molecular structure of the gene upon which it impinges. The ordinary environment of the gene affords a sufficient set of conditions to permit of change in the gene. So important is mutation for evolution and ontogeny that we have, naturally, sought to induce gene mutation, or otherwise control it, by external agencies in our hands. The attempt at experimental modification of the germ plasm is thus a part of our program. While little success has been gained in directing gene mutation so as to produce new bodily characters, marked progress has been made in controlling the rate of gene change, especially by the use of radiations.

The genes lie in chromosomes; and those genes that lie in the same chromosomes are linked together in their performance. By breaking up the chromosomes and by inducing them to make new combinations, the course of inheritance is changed, it may be, for generations. These chromosomal mutations are occurring apparently under conditions as found in nature. They may be accelerated by the direct action of intense radiations. This acceleration of chromosomal and gene mutations by the use of radiations is of great practical importance in our program.

Inasmuch as genes are controllers of development, with the cooperation of environment and under the conditions imposed by it, the tracing of the development of the organisms we are investigating, whether delphinium, mouse or man, is an essential part of our work.

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STAFF

The Director has continued his studies on child development and has cooperated in the Report on Child Development for the White House Conference. He has also drawn up plans for the Genetics section of the Chicago Century of Progress. He presided over the International Federation of Eugenical Organizations whose meeting was held in Rome. A. F. Blakeslee has continued his researches on mutation in Datura, with the assistance of A. G. Avery, Dr. Dorothy Bergner, J. S. Potter, made available to us by the Radiation Committee, National Research Council, and the collaboration of Professor John T. Buchholz. During the summer Dr. Blakeslee was assisted by several cytologists. H. H. Laughlin, assistant director at the Eugenics Record Office, continued his analysis of heredity in the thoroughbred horse, with financial support from Mr. W. J. Salmon, and in inventors, with the assistance of Miss Edith Banta. A. M. Banta and Thelma Wood continued their investigation of Daphnids with the aid of Dr. L. A. Brown during the summer. Banta made numerous contacts helpful for his work while at Brown University, and he has accepted the urgent invitation of the University to fill a research professorship there. His going brings a severe loss to the Department; he will continue for a time his work here during the summer. C. W. Metz continued his work on Sciara with assistance from Dr. Helen Monosmith and, later, Dr. H. B. Smith, as well as Mr. Adrian Ter Louw (part time) and Miss Louise Schmuck (under a fund of the Sex Committee of the National Research Council). Dr. M. Demerec has continued his study of mutable genes with the aid of Mr. Farrow. Dr. E. C. MacDowell continued his work on the genetics and development of mice, with the assistance of Mr. T. Lanes and Miss Jean Marsh, and made contacts with Doctors M. N. Richter and Philip E. Smith of the College of Physicians and Surgeons, New York City. Dr. MacDowell organized this Department's share in the annual exhibit of the Institution and is chairman of the Exhibits' Committee of the Sixth Genetics Congress. Dr. Oscar Riddle has continued his cooperative research in basal metabolism with Dr. F. G. Benedict of the Nutrition Laboratory. Dr. Riddle also presided at the annual meeting of the Association for Study of Internal Secretions, Portland, Oregon, and served as chairman of the American Committee, Second International Congress for Sex Research. He has been assisted by Miss Pela Fay Braucher and Mr. Donald Charles. Dr. H. J. Banker continued his study of inheritance of scholastic capacity. Dr. M. Steggerda was appointed in June to do field work in eugenics. Members of the Department have participated in conferences, called by President Merriam, in which the biological interests have been represented.

Among visiting workers at the Laboratory have been Dr. A. B. D. Fortuyn of Peking Medical College and Dr. Robert Nabours of the Kansas Agricultural College.

DETAILED REPORTS ON CURRENT INVESTIGATIONS

MUTATION IN RELATION TO THE GERM PLASM

DATURA

The jimson weed continues to yield mutations whose relations to a series of modifications of the standard condition of 12-chromosome pairs is being worked out by Blakeslee and his associates. The types of chromosomal modifications which are responsible for the chromosomal mutations of Datura are shown in Table 1. The chromosomes are recognized microscopically first by size and designated by the initials of the adjectives Large (very), large, Medium (+), medium (−), Small and small (very). Special modifications (humps) serve secondarily to further distinguish chromosomes of the same size.

In mutations called primary (Col. 3), an extra chromosome is added to one of the twelve; this is like the other two of the group of 3 (trisome) thus made. Its two ends are designated by numbers. In mutations called secondary the extra chromosome is made up by the doubling of only one half, or terminal portion, of a chromosome. In column 2 this half chromosome is indicated by the odd number of the numbered ends of the primary chromosomes. Complementary to this is the extra chromosome made up of the two even-numbered ends (Col. 4).

In mutations called tertiary, the extra chromosome is made up of united end portions from two non-homologous chromosomes. These are listed in column 5; each one twice.

Secondaries have been discovered for all except the smallest two chromosomes. For four chromosomes both the initial and the complementary secondaries are known (Cols. 2 and 4). The tertiary chromosomes DS, Wy, and SE have been isolated from cryptic chromosomal types found in nature, that had originated, presumably, through segmental interchange. The tertiary chromosomes Mp, ES and X were formed in cultures of our standard Line 1, presumably through segmental interchange. The other named tertiaries have been induced by radiation-treatment. Of the tertiary chromosomes represented by figures in parenthesis, the ends are known, but their somatic effects when present as extras have not yet been adequately studied; they have been variously obtained. The primary, secondary and tertiary (2n + 1) types are recognizable without microscopic examination by the morphological, somatic effects produced by the presence of the extra chromosomes or new combinations of fragments of chromosomes

Blakeslee reports further:

"Secondaries are useful as chromosomal testers since their double half chromosomes enable one to identify microscopically the ends of chromosomes attached to them in configurations of several attached chromosomes. Although no secondary, as yet, has been found for Gl and Ix, we are able to label the two ends of the Gl chromosome (21·22) by means of the races from Peru which have the modified chromosomes 11·21 and 12 22 as well as by certain other races from nature which have the modified chromosomes 3·21 and 4 22. Since it is a fragment of Ix which is joined to Sp in a translocation obtained from X-ray treatment, there is now in our standard

Line 1 no chromosome the two ends of which we are not able to identify microscopically by making crosses with the appropriate testers. In no other plant have the ends of the chromosomes thus been labeled.

Table 1—*List of primaries, secondaries and tertiaries arranged by size of chromosomes in the trisomic set. Ends of chromosomes are designated by numbers 1 to 24*

1	2	3	4	5	6
Chrom. size class	Secondary chrom. and (2n + 2/2) type	Primary chrom. and (2n + 1) type[1]	Complementary secondary chrom. and (2n + 2/2) type	Tertiary chrom. and (2n + 1) type	Genes located in particular chromosome.
L......	Py (1·1)	Rl (1 2)	Sg (2·2)	DS = 2·17 Wy = 1·18 ES = 2·9 Ph = 2 5 Hg = 1 9 tr Sg = 12 11·2	p in Wy
l	Sm (3·3)	Gs (3·4)	....	Mp = 4 6 (3·21) (4 22)	fw, Bs in 4 half QS in Gs, half not yet determined.
l	St (5·5)	Bk (5·6)	At (6 6)	Mp = 4 6 Ph = 2 5	
M......	Un (7·7)	El (7·8)	....	. ...	.. ..
M°.....	Mt (9 9)	Ec (9 10°)	Th (10°·10°)	SE = 9·20 (10 19) ES = 2 9 Hg = 1·9	MS in either Ec or Sp.
M°. ...	Wd (11·11)	Ck (11·12°)	. ..	trSg = 12 11 2 (11·21) (12 22)	in, tf, e, sky, in 12 half
M.. ..	not named (13·13)	Mc (13 14)	not named (14 14)	X = 18 13	
M. ..	Sc (15·15)	Rd (15·16)	. .. .		tc in 16 half
m.....	Df (17 17)	Pn (17·18)	. ...	DS =2 17 Wy = 1·18 X = 18 13	c, wt in 17 half p in 18 half
m°	Dv (19 19)	Sp (19 20°)	.	SE = 9·20 (10 19) trIx = (20·19 23)	sh. MS in either Sp or Ec
S°	.	Gl (21° 22)	. .	(3·21) (4·22) (11 21) (12·22)	sc, bb, pl
s. ..	. .. .	Ix (23·24)	... .	trIx = (20 19·23)	sw

The ends 10°, 12°, 20° and 21° are characterized by terminal humps.

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[1] The full names, of which abbreviations are given below, are published in Year Book No. 25, p. 40.

"Eighteen genes have been located in particular chromosomes, and as many more are in process of being located chiefly by the method of trisomic ratios. New genes in considerable number are being obtained by radiation treatment. Genes are useful as labels with which to follow the behavior of chromosomes and parts of chromosomes.

"Types with a chromosomal fragment extra, of which we have several (3 of them in the homozygous condition), are not represented in the table. Forms with various combinations of the extra chromosomes listed in the table have been identified, such as (2n + 1 + 1) types with the extra chromosomes consisting of two similar or two different primary chromosomes; a primary and a related or unrelated secondary chromosome; a primary and a tertiary; a secondary and a tertiary; and a primary and a fragment."

COMPENSATING TYPES

On these Blakeslee reports as follows:

"A compensating type is characterized by this: Parts of two different, composite, chromosomes together form the equivalent in genic content of a whole normal chromosome (the compensate), leaving the remaining, non-compensating parts of the two composite chromosomes to effect somatic idiosyncrasies or abnormalities. Such types are being specially studied in order (a) to analyze the somatic effect of parts of chromosomes and (b) to purify chromosomally aberrant races without the necessity of microscopic study.

"(a) The following kinds of compensating types represent those which have been identified or may perhaps be synthesized from the chromosomes available.

"1. Compensation between a secondary and a tertiary:

> "Examples: α, unnamed type with series of composite and normal chromosomes as follows: **17**·*17*—17·18—*18*·**1**—1·2—2·1. One of the *17* portions of the secondary chromosome 17·17 compensates with the *18*-portion of the tertiary 18·1 to form the genetic equivalent of a 17·18 chromosome leaving the portions **1** and **17** as excess chromosomal material to effect morphological changes in the adult plant. (In this, as in the following cases, the parts that compensate are shown in italics and the parts that remain as extra chromosomal material are shown in bold face type.) β, GD with formula **17**·*17*—17·18—*18*·**13**—13·14—14·13. γ, unnamed type with formula **3**·*3*—3·4—*4*·**22**—22·21—21·22. δ, B T = **10**·*10*—10·9—*9*·**20**—20·19—19·20.

"2. Compensation between two tertiaries

> "Examples: α, Nb=9 10—10·9—**9**·*1*—1·2—*2*·**5**—5·6—6·5. β, MD= 9·10—10·9—**9**·*1*—1·2—*2* **17**—17·18—18·17. γ, unnamed type=13 14—14·13—**13**·*11*—11·12—*12*·**17**—17·18—18·17.

"3. Compensation between fragment and secondary.

"4. Compensation between fragment and tertiary.

"Types with 6 or more chromosomes strung together in a circle are being secured in considerable numbers, chiefly by irradiation; from such, at least one compensating type involving 2 tertiary chromosomes may be expected. By the combination of compensating tertiaries from such circles and by compensations with secondaries and fragments, a large number of compensating types can be secured." They represent in Blakeslee's view a new means of bringing about somatic changes in an organism. Together with primary, secondary and fragmentary types they afford a method, which bids fair to become of economic importance, of securing novel varieties in plants by means of chromosomal alterations.

"(b) Compensating types are of service in our breeding procedure, as can be illustrated with Nubbin (Nb) whose formula is given above. If Nb is crossed with a 'B' race which has the modified chromosomes 1·18 and 17·2, there results an Nb with a chain of 9 chromosomes, as follows: 9·10—10·9—9·1—1·18—18·17—17·2—2·5—5·6—6·5. The 1n gametes of such a plant should always contain the 'B' chromosomes (1·18 and 17·2) and their 2n offspring from selfing, therefore, should all be 'B.' The above expectation is fulfilled by cytological findings of Dr. Bergner. A similar condition has been found to hold for the compensating type MD, listed above. It seems safe to generalize and make the following statements. If a compensating type is crossed with pollen from a race derived by segmental interchange with the chromosome involved in the compensation, then all the *n* gametes have the same chromosomes as the pollen parent. Thus, without microscopic examination, one can be certain of the chromosomal constitution of the offspring from such hybrids with compensating types. The use of such types has enabled us to demonstrate crossing-over of genes between chromosomes in attached chains and to transfer genes from a primary to a tertiary chromosome without the necessity of chromosomal study."

Blakeslee reports further:

"The survey of races of *D. stramonium* from nature has been continued and we are now able to report on 493 races representing collections from widely separated parts of the world. Only 4 main chromosomal types, in addition to our standard Line 1, have been discovered by the attached configurations which they induce in F_1 with our standard Line 1. Line 1 is the commonest type in North America and the only type found in Brazil. Elsewhere it is rare. The 'B' type is the commonest elsewhere and induces in F_1 with Line 1 a circle of 4;

$$\begin{array}{lcr} 1\cdot2 & - & 2\cdot17 \\ | & & | \\ 1\ 18 & - & 18\cdot17 \end{array}$$

The third, or Peruvian type, induces in F_1 a circle of 4;

$$\begin{array}{lcr} 11\ \ 12 & - & 12\ \ 22 \\ | & & | \\ 11\cdot21 & - & 21\ \ 22 \end{array}$$

The fourth, or Jamestown type, was found in Jamestown, Virginia, and in a few other localities. It induces a circle of 4;

$$\begin{array}{lcr} 3\cdot4 & - & 4\ \ 22 \\ | & & | \\ 3\cdot21 & - & 21\cdot22 \end{array}$$

Both the third and fourth types may at the same time be 'B'.

"The fifth type induces a figure of eight made up of two bivalents which are connected by their humps. Our present tentative interpretation is that in the formation of type 5 from Line 1 the humps on the ends of the $9\cdot10^{\circ}$ and $19\ 20^{\circ}$ chromosomes became interchanged and that attachments are possible between like humps as well as between like portions subterminal to the humps. Special study with other technique than the acetocarmine method will be necessary before we are sure that the humps are satellites as some evidence suggests. The tentative formula for the F_1 is:

$$\begin{array}{ccc} & 10^{\circ}-{}^{\circ}10 & \\ 9\cdot10 & & 20\cdot19 \\ | & 20^{\circ}-{}^{\circ}20 & | \\ 9\ 10 & & 20\cdot19 \end{array}$$

F_1 with this type has 50 per cent aborted pollen grains and ovules. Type 5 has been found in combination with types 1, 2 and 4.

"The B type has been chosen for intensive study to further test the hypothesis that it differs from our standard Line 1 by segmental interchange between two non-homologous chromosomes. It has been crossed on to secondary, tertiary, translocated and fragment types and the resultant configurations have been studied by Dr. Bergner cytologically. In all cases the configurations found have been those predicted. Of especial interest is the configuration in the secondary Df rendered homozygous for the 'B' chromosomes. The medium-sized Df chromosomes (17·17) formed a circle of 3 with the 2 large 'B' chromosomes (2·17). Of, homozygous for Line 1 chromosomes, forms a circle of 3 small medium chromosomes (—18·17—17·17—17·18—). Another confirmation of expectation was obtained by finding a circle of 8 in a hybrid between a Line 1 tetraploid and a 'B' tetraploid. The only unexpected result in all our tests with the B type is the increased vigor of growth of the secondaries Df and Py when rendered heterozygous for B chromosomes. By the addition of secondary and tertiary chromosomes to the B circle, it is possible to distinguish the B from the Line 1 chromosomes within the circle. By cytological examination of the proper hybrids, Dr. Bergner has been able to determine that the Line 1 L (1·2) is slightly larger than the 'B' L (2·17) chromosome and that the Line 1 m (17·18) is slightly smaller than the 'B' m (1·18) chromosome. The four components in the 'B' circle, therefore, can be identified by their sizes in good preparations. The peculiar bipartite appearance of the Line 1 m (17·18) chromosome suggesting the result of interchange, together with the world-wide distribution of the 'B' races, suggests that the 'B' may be the original type and that our standard Line 1 may have been derived from it by unequal interchange of the 2·17 and 1·18 chromosomes. The B race has been rendered similar to Line 1, except for the modified chromosomes, by continued back-crossing to Line 1 and the morphological effects of the modified chromosomes studied in (2n+1) tertiaries containing these 'B' chromosomes as extras. The other cryptic types from nature are being investigated in similar manner.

"A peculiar race, the only one in a considerable collection from Hungary, contains a recessive gene which in the homozygous condition causes a doubling up of chromosomes. Apparently when the doubling occurs early in microsporogenesis, twin nuclei are formed. In both single and twin nuclei further doubling may take place, producing nuclei which may contain as many as 96 chromosomes. A further peculiarity is that the normal bivalent arrangement may be retained instead of the usual formation of tetravalents in 4n cells. Such a condition with bivalents instead of tetravalents in a cell with the doubled number of chromosomes has been called 'double diploidy.' Cells have been found which contain at metaphase 12 or 24 tetravalents, 12, 24, or 48 bivalents Sometimes the twin nuclei fuse; sometimes not. Formation of 4, 6, and 8 pollen grains from one P.M.C. has been found. They contain 12, 24, or 48 chromosomes each. The size of the P.M.C. and the pollen grains is proportional to the number of chromosomes they contain. The meiotic reduction must be regular because very few aborted pollen grains are found."

DIFFERENCES BETWEEN SPECIES

"One of the major problems of genetics is the origin of species. The determination of chromosomal types in varieties of a single species, *Datura stramonium*, by means of intra-specific hybrids has suggested a method of origin of these types and has provided a technique for the study of differences between species by means of interspecific hybrids.

"A re-examination of the interspecific crosses *Datura stramonium* x *D. ferox, D. stramonium* x *D. quercifolia* and *D. ferox* x *D. quercifolia* has led to the following tentative conclusions regarding these three species which all belong to the *stramonium* group. (1) The *ferox-quercifolia* hybrid shows only 1 chromosomal configuration involving 4 chromosomes, a figure of eight type of configuration. Chromosomally it looks more normal than many intra se *stramonium* hybrids. These two species, though distinct, resemble each other morphologically more closely than they do *D. stramonium.* (2) Both *ferox* and *quercifolia* are B races of some sort. (3) Both *ferox* and *quercifolia* when crossed with *stramonium* show a Peruvian-like type of configuration. (4) Both show when crossed with *stramonium* a third configuration, apparently different from any type found in intra se *stramonium* crosses. The chromosomal constitution of these three species is being studied further by crosses to appropriate testers and by isolation of the different modified chromosomes as extras in plants with otherwise Line 1 chromosomes

"Preliminary studies are being made of hybrids between species in the *stramonium* and those in the *meteloides* groups. Ultimately it is hoped we may be able to present data on differences between chromosomes of the available species within all the different groups of the genus *Datura.*"

DELPHINIUM

A rose-colored variety of the larkspur contains a gene (rose-alpha) that mutates frequently to the "wild" purple allelomorphic gene. Demerec, who has been studying this phenomenon, reports as follows:

"Somatic reversions produce purple spots variable in size, the small ones being caused by reversions occurring late in the development of the plant, and the large ones being a product of early reversions. The size of the spots, therefore, can be used as an indication of the time at which the mutation occurred; and by assuming that, on the average, each cell generation doubles the size of a spot, it is possible, by counting the spots of different sizes, to determine the frequency of mutability of the gene during several cell generations. The cells of the sepals and petals of Delphinium are fairly large, making practicable the classification of the purple spots in different size classes according to the number of cells they contain. It has been found that the smallest purple spot has one reverted cell only. Measurements made for the rose-alpha gene indicate that the gene mutated with approximately the same frequency during twelve cell generations of flower development, the average frequency in the material measured being about 70 mutations per one million cells. No difference in mutability was observed when the gene mutability during eight cell generations of the development of the sepals of the lowest five flowers of a raceme was compared with the mutability during the same period of the development of the next five flowers of the same racemes. In both cases the mutability curves were practically horizontal lines. The mutability curves in material differing widely in the frequency of mutability were also almost horizontal. The rare occurrence of the purple plants among the offspring of rose-alpha parents (28 purples among 3865 individuals) and the rare occurrence of plants with large purple sectors indicate that the germinal mutability and the early somatic mutability of rose-alpha gene is low and probably not different from the mutability of the gene during the development of flowers.

"The mutability of rose-alpha genes was observed during four sexual generations in the material in which, at the beginning of the experiment, all rose-alpha genes traced their origin to a single gene. The line was propagated by self-pollination and only plants heterozygous for rose-alpha were used for comparison. The rate of mutability was expressed in terms of the number of spots (mutations) per area of one thousand square millimeters. In each family the mutability rate of from eight to nineteen plants was determined. In F_1 generation the average mutability rate of rose-alpha gene for the family was 1182.18 ± 90.26; in F_2 generation the average mutability rate was 1198.41 ± 61.91; in F_3 generation the mutability rate of the family *a* was 1241.24±109.19, and the family *b* 1266.80±47.89; and in the F_4 generation the mutability rate of the family *a* was 1588.46 ± 112.12, family *b* 1413 45±62 74, family *c* 859.93±35.01 and family *d* 1239.14 ± 94.43. It is evident that the *c* family of the fourth generation is the only one in which the rate of mutability differs significantly from the rate of mutability of the other families. In all other cases the rate of mutability of rose-alpha gene has not been changed to any significant extent. In the results of this experiment there is not the slightest evidence that the splitting up in the rate of mutability of the mutable gene in subsequent generations took place, but the results rather suggest that the rose-alpha gene retained to a high degree its characteristic rate of mutability."

Demerec points out that the constant rate of mutability speaks against the view that the genes are complex structures composed of two kinds of smaller independent units. He thinks the hypothesis is favored that the frequent mutability of mutable genes is due to a high chemical lability of these genes. The changes, then, are probably of a chemical nature rather than of a physico-mechanical one. Demerec has also—

"made measurements on the rate of mutability of rose-alpha gene in plants homozygous for rose-alpha and in the plants of the same families heterozygous for rose-alpha. The measurements were continued for three generations. The rate of mutability was determined on a total of 43 homozygous and 73 heterozygous plants. The average number of spots per thousand square millimeters was 2276 in the homozygous plants and 1235 in the case of heterozygous plants. Apparently, in the homozygous plants twice as many mutations occurred as in the heterozygous plants, which is to be expected since homozygous plants had two rose-alpha genes and heterozygous plants only one."

DAPHNIDÆ

In Year Book No. 28, p. 42, reference was made to Banta's experiments which supported the hypothesis that during parthenogenetic reproduction lethal and sub-lethal mutations arise but are ineffective and may be carried along and accumulate in number and kinds during the generations.

New data supporting the hypothesis have been obtained during the current year. These have been summarized by Banta as follows:

"1. In cases (2) where parthenogenetic lines (clones) taken from the wild have been inbred in sexual reproduction after a very limited period of parthenogenesis, the fertilized sexual eggs have hatched relatively very well;

there was no early mortality among the hatched young; none was sterile; and the degree of fertility (productivity) of the hatched offspring was high.

"2. In every case, except one, in which a clone has been inbred after 50 or more generations of parthenogenesis it has exhibited lower hatchability of the sexual eggs, greater early mortality among the hatched young, more sterility, and a lesser degree of fertility of the hatched individuals than has occurred among clones inbred after relatively few generations of parthenogenesis.

"3. In cases in which the same clone was inbred after a lesser and again after a greater period of parthenogenesis, the earlier hatches have been better, early mortality and sterility have been very much less and the productivity of the hatched individuals has been much greater as compared with the results of inbreeding the same identical clone after a more prolonged period of parthenogenesis.

"4. In every case in which clones were first inbred and then cross-bred to other clones previously tested in inbreeding, the results of the cross-breeding were superior to those of the inbreeding of either of the parent clones, *viz,* hatchability (so far as the present indications from incomplete data show) is better, early mortality and sterility are lower and the fertility is immensely better."

Examples of the kind of data upon which the foregoing conclusions are based are as follows: Clone XI, when *inbred,* after its 193d parthenogenetic generation hatched 21 per cent of its eggs and 33 per cent of the young hatched were fertile. After about 400 inbred generations, not one of its eggs hatched. Clone 1622 had a comparable history. When these two clones were cross-bred, the fertility of the young produced is over 77 per cent.

Last year's conclusion seems to be confirmed, that inbreeding permits recessive, even semi-lethal, mutations to accumulate in the clone.

To the foregoing generalization one exceptional case appeared.

Clone 1284, after 289 parthenogenetic generations, gave on inbreeding a hatchability of about 47 per cent, and over 76 per cent of hatched young were fertile. When cross-bred with Clone 1622, 87 per cent of the hatched young were fertile. Apparently Clone 1284 has undergone little semi-lethal mutation. The frequency of mutation varies in different clones.

Among the mutations accumulated in parthenogenesis are some that influence the rate of growth, as considered in a later section, others affect general vegetative vigor, hardiness, productivity and even other traits.

EXPERIMENTAL MODIFICATION OF THE GERM PLASM

Until less than a decade ago, attempts experimentally to modify the germ plasm had yielded only negative results; but a decade of experimentation has shown that radiations of various types can have an effect. The nature of the effect is of two kinds.

CHROMOSOMAL MUTATIONS INDUCED BY RADIATION

Experiments with Datura

First, and most striking, is the effect upon the chromosomes—for these may be caused to fragment with resulting union of the fragments in many new combinations, with ends derived from different chromosomes. Some of the germinal results in the case of Datura have been considered by

Blakeslee in earlier paragraphs. Certain details of procedure in Datura are described.

"The most effective treatment is of dry seeds. Of 16 plants derived from treatment of seeds with an estimated dosage of 6000 to 8000 r units, we have obtained the following chromosomal changes: two cases with an extra fragment, 4 cases of a chain of 4, probably due to simple translocations, 10 cases of circles of 4, 2 cases of circles of 6. In addition the treatments have given 2 types not yet determined, which are probably extra chromosomal in nature, and 16 types which are classified as due to genes. Further, there are many cases of different percentages of aborted pollen grains. Some of those with 50 per cent aborted pollen were found to be transmitted through the eggs, but not through the pollen, and hence, since their chromosomes appear normal, are probably due to recessive genes which are lethal in the pollen. Dr. Buchholz has found numerous cases in which half of the pollen tubes either fails to germinate, or bursts in the style after germination or grows too slowly to effect fertilization. Since these different abnormalities are transmitted through the pollen, they are classified as recessive genes lethal to the male gametophyte. Methods have been worked out for locating the genes for pollen and pollen-tube abnormalities in the proper chromosome by means of linkage with visible genes. From the circles of 4, *'prime types'* have been isolated. Prime types are races homozygous for the modified chromosomes and induce the original circle when back-crossed to the standard Line 1. One of the translocations (20 19·23+24) we now have as a prime type. It is of interest that the fragment (23) when homozygous (23·23) behaves in the same way as the fragment (1) in the Sg·tr (12·11·2+1). When a plant is homozygous for either of these fragments, the pair of fragments can not close but forms an open bivalent. Since the two fragments in the pair are identical in content of genes, there must be something besides likeness of genes responsible for the attachment of chromosomes at reduction.

"Including the 4 cryptic types from nature and types isolated from radium and X-ray treatment, we now have a total of 13 prime types isolated In more than half of them, we know the ends which have been interchanged or translocated. The aberrant chromosomes involved in these prime types are being determined by crossing them with (2n+1) primaries, secondaries and tertiaries and by combining them inter se with other prime types, the chromosomal constitution of which is known. If a chromosome of Line 1 has been interchanged with a second chromosome to form a prime type and the same chromosome of Line 1 has been interchanged with a third chromosome to form another prime type, the hybrid between the two prime types will show an enlarged circle Thus hybrids between selected prime types, each of which induces a circle of 4 with Line 1, have given circles of 6. An example may be given from races in nature. The Peruvian type has the chromosomes 3·4, 11·21, 12·22 while the Jamestown type has the chromosomes 3·21, 4·22, 11·12. Each of these types in F_1 with Line 1 induces a circle of 4; in F_1 with each other, it induces a circle of 6 with the following formula:

$$\begin{array}{ccccc} 3\cdot4 & - & 4\cdot22 - 22 & & 12 \\ | & & & & | \\ 3\cdot21 & - & 21\cdot11 - 11 & \cdot & 12 \end{array}$$

In similar manner we have gotten in hybrids between selected prime types a chain of 8 and a circle of 10. These large circles can form the basis for compensating types and for (2n+1) tertiaries.

"Radiation experiments are being continued since we are in need of more testers, especially in the way of workable genes. We now have plants growing which came from seeds treated with X-rays with 20,000 r-units, measured with a Victoreen dosimeter. This is a dosage 2 to 3 times that estimated to have been given the 16 plants reported upon in an earlier paragraph and should give additional chromosomal and gene mutations. We also have growing this season F_1 plants derived from crosses between normal females and pollen treated with radium in experiments carried on by Dr. Buchholz. These plants have not flowered, but already a high proportion are obviously abnormal. Out of 409 from the higher dosages only 252 can, at present, be classified as possibly normal in appearance."

EXPERIMENTS WITH DROSOPHILA VIRILIS

The X-ray radiation was extensively used in the experiments with *Drosophila virilis*. It has been possible to extend the scope of this work because of the support given by the Committee on the Effects of Radiation on Living Organisms of the National Research Council which paid the salary of a research assistant, John G. Farrow, to work under Dr. Demerec. Demerec reports as follows:

"It has been found that the X-ray radiation did not produce any appreciable change in the mutability of mutable reddish-alpha, miniature-beta and miniature-gamma genes. These results support the conclusion reached by Muller and Mott-Smith that the natural radiation could be responsible for but a very small proportion of genic changes occurring in nature. If natural radiation were largely responsible for changes in genes, as it has been suggested, then the X-ray treatment should increase the mutability of mutable genes appreciably, since it has been shown that the genetic effect of X-rays is almost directly proportional to the dosage applied."

Demerec has, however, found that, as the number of r-units increases, there is in the lower part of the scale (from 500 to 1200 units) an increase in per mille frequency of non-disjunctions of chromosomes from 7 to 15; while from 1200 to 4000 units the increase is slower, 15 to 18. Also the number of offspring is decreased by X-rays comparatively little from 0 to 1200 r-units; but from 1200 to 4000 units it diminishes from 135 to 15 per female. Demerec suggests the hypothesis that the decrease in number of offspring per treated female is responsible for the flattening out of the non-disjunction curve above 1200 r-units, for the offspring that are killed would probably have shown non-disjunction in a larger proportion than did those that survived.

TABLE 2—*Primary non-disjunctions of X-chromosomes in Drosophila virilis*

Treatment	Number of cultures	Regular		Exceptional		Per cent of except. males	Ratio of except. females to males
		Females	Males	Females	Males		
Controls	309	20871	16316	2	23	0 141	1:11.5
X-rayed	542	34849	30960	17	338	1 09	1:19 9
Total ...	851	55720	47276	19	361		1:19

Frequency of non-disjunction of the X-chromosome—Demerec has computed the incidence of primary non-disjunctions in *Drosophila virilis*, untreated and treated with X-rays (Table 2). While the frequency of non-disjunctions in the controls of *D. virilis* is about double that of *D. melanogaster*, the ratio of exceptional females to males is much lower in *virilis* than in either *melanogaster* or *similans* as 1 : 19 is to 1 : 5 and 1 : 13 respectively.

EXPERIMENTS WITH ORTHOPTERA

Nabours, who X-rayed about 141 male grasshopper-like Tettigidæ, mostly of the species *Apatettex eurycephalus*, has obtained about 120 offspring from the first 25. He reports that—

> "All have been apparently unaffected by the X-raying, except one male which carried a dominant element in his color pattern complex entirely unknown in this species—a broad white stripe. Unfortunately he was lost during his 4th instar."

GROWTH STUDIES

The increase in size of the developing animal is a biochemical process which is, of course, possible only under environmental conditions favorable for such processes, but which is primarily initiated by the nascent organism, which takes from the environment what it needs or can utilize of what the environment offers.

Nutrition is thus seen to be only a part of growth; the water-imbibing mechanism and the specific metabolic machinery are no less important. The capacity for and the mechanism of growth are clearly genetical properties and it is primarily those that we are here investigating.

DAPHNIDS

Among one of the hypotheses which require testing is that proposed by Robertson, namely, that a number of small organisms in a given minimum volume of culture medium will grow more rapidly than one alone because of the production and excretion into the water of a mutually stimulating substance, called allellocatalytic substance.

Using one of Banta's Cladocerans, *Moina macrocopa*, as the experimental animal, Miss Maurita McPherson, working here during the summer, set up—

> "experiments both with varying numbers (1, 3, 6, and 9) of young sister *Moina* in like amounts of a given culture medium; and the same number of sister *Moina* in different dilutions of the concentrated culture medium. The time elapsing between the beginning of an experiment and the production of the first clutch of young by the experimental and control animals (of the same litter) was the criterion of the rate of development. The rate of development should, of course, be accelerated by any mutually stimulating substance produced by contiguous animals.
>
> "Her findings, to date, are that in a given culture medium the single mother will produce young first if the medium is quite weak; the 3 mothers first if the medium is somewhat stronger; and the 6 and 9 mothers to a bottle first if the medium is fairly or very strong. In the different concentrations of culture medium the mothers release their young first in accordance with the optimum strength for the number of animals in the given quantity of the given strength of culture medium. In the series with

varying numbers of animals in the same amounts of the same strength of culture medium as that in which the single mother released first, the 3, 6, and 9 mothers were retarded and the more retarded in proportion as their numbers were larger. Conversely, with the same set-up, when the culture medium was so concentrated that the 9 mothers released first, the 6, 3, and 1 animals were retarded, and the more retarded in proportion as their numbers were smaller.

"The conclusions, then, are (1) that greater than the optimum strength of culture medium for 1 or 3 or 6 or 9 mothers in a bottle in some manner operates to retard rate of development; (2) that less than the optimum strength likewise produces a retarding effect, due to food limitations; (3) that concentration of food may account for the phenomena of varying rates of development of varying numbers of animals in a given quantity of culture medium without reference to any mutually produced growth-promoting substance; and (4) that she finds no need for, nor evidence of, an allelocatalytic substance."

Associated with these results, some studies made at Banta's suggestion by Dr. C. H. Stuart of Brown University, are of importance. The problem was the nature of the food of *Moina* that is living in the culture medium of manure-solution. Dr. Stuart first sterilized individual *Daphnia longispina,* then reared them through successive generations upon a single species of bacterium. It emerged that *Daphnia* grows and reproduces satisfactorily only upon *living* bacteria, that it gains little nutriment from sterile broth or sterile protein debris and that different bacteria have different food values for *Moina.*

As development and maintenance are dependent upon oxygen consumption, it was of interest to see whether different clones of daphnids required the same amount of oxygen. By means of the manometer described in Year Book No. 28, p. 43, Miss Wood has obtained measurements of oxygen consumption, the unit being the displacement in millimeters per hour per unit size (cube of length) of the animals measured. Thus individuals of Clone B, a very vigorous clone, yielded an average displacement of 0.181 mm. per hour per unit of body size. For the weak Clone B 3, the result was 0.137. These two clones are sister clones, both derived from Clone XI. In view of such differences (33 per cent) in metabolism of different clones, we may look for differences in the rate of growth of different clones of *Daphnia longispina.*

RATE OF GROWTH OF DAPHNIA

Eleven clones of *Daphnia,* each arising from sexual eggs derived by inbreeding, seven of them being very closely related, were reared contemporaneously under as nearly as possible identical conditions, though not in a constant temperature apparatus. From each clone, on the same day, 5 or more newly-released sister-young were selected for study, measured daily, and of each lot an outline of one was drawn after each molt. At the end of 6 days the average length of the different clones runs from 0.6 to 1.6 mm.; at 30 days from 1.7 to 2.6 mm. In one clone individuals develop exceptionally slowly at first; then with high velocity. In another clone the individuals develop more rapidly at first but at 30 days are no larger than those of the first clone. One clone is characterized by dwarfness, having at 30 days less than one-third of the bulk of the average of our daphnias. Thus while members of any line are remarkably alike in their growth curves different lines have curves of growth that differ in their characteristic shape and especially in their gradients as a whole. There are striking differences in innate capacity for growth in closely related lines of one species.

PIGEONS

A study of the growth curves of two extremely small races of pigeons (Tipplers, Magpies) and two very large races (Runts, Homers) is being made by Riddle in collaboration with Mr. Donald Charles.

Inasmuch as the size of pituitary and thyroid glands of the races studied has also been determined it is believed that the completion of the study should contribute to our knowledge of the rôle that these glands play in the growth process and in establishing race differences in size.

MICE

Studies on growth of mice, reported in Year Book No. 28, pages 46 to 48, have been continued under MacDowell's direction by Mr. T. Lanes. It will be recalled that MacDowell found that mice in reduced litters, thus obtaining extra mother's milk, grew much faster than normal. The new studies reveal that the effect of the larger quantity of mother's milk persists long after weaning, though eventually, after 2 to 2½ months, the control mice tend to catch up with their more favored sisters.

MAN

Since 1921, the Director of this department has been following the course of physical development of 150 boys and girls of the Orphan Asylum of Brooklyn and of about 200 boys of Letchworth Village. He has also collected data on 500 "Mongoloid dwarfs." During the current year these data have been subjected to statistical analysis and it is expected that a report upon the results may be completed in the next year.

Adolescent Spurt and Slump

In 1927, the Director called attention to the curve of increments of growth during the adolescent period as obtained from mass statistics of many thousand boys. This curve drawn on a time-kilogram-annual-increment scale gave a striking binomial curve and in so far supported for this age-period Robertson's theory of a special growth activator. The practice of measuring the same boy at successive 12-months' periods has given a wholly new interpretation to this curve. It appears that the period of adolescent spurt which in the mass extends from 10 to 18 years, with its mode at 14½ years, is merely a composite and does not represent the adolescent spurt of any individual. For, in the individual, the extra spurt may be passed through in 24 months or less and naturally, at the maximum, far exceeds the 5.75 kg. annual increment found in my composite curve. In some cases 10 to 13 kg. may be added in a single year. It is because the age of this maximum may extend from 12 to 17 years (with the modal age at 14 to 15 years) that a Gaussian curve is formed in mass statistics; and the form of that curve has nothing to do with Robertson's theory of growth.

It appears also that 1 to 3 years before the adolescent spurt reaches a maximum there is a marked slump in the velocity of growth. This is more marked in the boy than in the girl. On the one hand it is associated with a delay of the onset of puberty in the boy; on the other it permits the girl to pass the boy in stature and weight at about 11 years of age. The boy, as it were, hesitates a long time on the brink of puberty.

The form of the individual curve of the growth-spurt is very varied. In many cases only a single main spurt is shown; in other cases a major and one or more minor spurts appear. The episode, often brief, is of the greatest importance for the boy or girl. It deserves further study as a physiological phenomenon and this, with the aid of Dr. F. G. Benedict of the Institution and Dr. A. N. Bronfenbrenner of Letchworth Village, it is hoped to start. From the fact that the period of adolescent rapid growth is also one of rapid development of gonads and secondary sex characters, it is concluded that secretions of the gonads play a part in stimulating growth.

Racial Growth Differences

That the chief races of mankind differ strikingly in their proportions has long been recognized. The relatively short-legged Chinese and Amerinds differ from the long-legged Negroes, and these differences are clearly due to differences in the growth processes that affect the length of the appendages. It is a problem of much interest to determine how early in ontogeny these differences appear, to learn when, in the course of development of the child or fetus, these differences in localized growth first make their appearance. The data on growth and differentiation that we have collected are now being analyzed by race.

Sexual Growth Differences

The boy and the girl do not grow in the same way. Under the influence of unlike sex chromosomes in last analysis and of unlike endocrine secretions more immediately, the appendages of the girl begin to elongate rapidly, on the average, at a time when this elongation in the boy still retains its childish rate of increments. Also, the rate of growth of various portions of the body and the length of time during which they grow are not the same, so that the finished bodies of male and female are as unlike in form as in function. The differential factors that result in this adult sex difference it is hoped eventually to investigate.

Abnormal Growth Processes

Dwarfs, occurring either sporadically or in hereditary—even racial—strains, make their appearance in man, as in mice. It is hoped, with the aid of studies on mice and other mammals, that further insight will be gained in the factors of such irregular growth.

With these various studies now well under way it is hoped to lay the foundations of a branch of science whose development has been too long delayed and which may be called Comparative Human Auxology.

SEX STUDIES

Fundamental to genetics, if not to all biology, is that duplicity in organisms that we call sex. Present already in the lowest (of non-parasitic) organisms it is practically coëxtensive with life, and the question of its origin is apparently one with the question of the origin of living matter. Like other characters its expression in successive generations is insured by the chromosomes. Its importance is emphasized by the circumstance that the two sexes differ by nearly a whole chromosome. It is a consequence of that difference, apparently, that the protoplasm of the two sexes is fundamentally unlike and that the egg so often awaits its fusion with the sperm before it proceeds to development; or, at least, even in the lowest organisms, a fusion of dissimilar nuclei periodically occurs.

Our work on the more fundamental phases of sex is temporarily interrupted. Our work on the association of sex differentiation with chromosomal differences is being continued in flies; and in them and in Daphnids is being investigated something of the mechanisms by which in different organisms the sex ratio is controlled Finally, in pigeons, are being worked out some of the deeper lying differences in the developmental processes by virtue of which the alternative of either a male or a female body with its characteristic differences in form and function is determined and these somatic differences realized.

DAPHNIDS

Banta and Dr. Stuart of Brown University have elaborated a method of controlling the sex-ratio of daphnids. They use a filtered manure solution, low in bacterial content, and place equal amounts of it into a number of equal containers. In each container is placed a constant number of sister *Moina* young and the set is given bacteria whose amounts form a graded series. In such experiments the most heavily fed females produce only female young, while those less and less well-fed produce an increasingly higher percentage of male young—except that toward the end of the series the percentage of male offspring falls off.

In these experiments, in confirmation of results obtained by Banta and Brown, male young are produced more slowly than female young. Excessive retardation, due to insufficiency of food at the end of the series, results in a smaller proportion of male offspring.

EXCRETORY PRODUCTS OR QUANTITY OF FOOD?

The findings described in the preceding paragraph (control of male production by scarcity of food) suggest that the reason for male production in crowded bottles is shortage of food rather than increase of excretory products, as concluded by Banta and Brown (Year Book No. 26, p. 52). This possibility has led Banta to new experiments as follows: A filtrate of old manure solution, low in bacteria, was distributed into 8 unequal bottles containing respectively 70, 50, 30, 20, 10, 7.5, 5 and 2.5 milliliters of the fluid to each of which 1 milliliter of a suspension of bacteria was added; together with 3 young sister *Moina*. While the volume of the medium varied, the form remained nearly constant in the 8 bottles. Thus amount of food was constant, but volume of medium to receive excretory products, hence the density of such products, varied. It always resulted that the percentage of males produced was greater as the density of the excretory products increased. Other experiments support the conclusion that both food scarcity and accumulated excretory products may be factors in the control of male production.

SEX OF YOUNG FROM SEXUAL EGGS

Banta calls attention to the facts that, first, sexual eggs of *Cladocera* produce only female young and that, second, Miss Wood, by excellent technique, is able to hatch nearly 50 per cent of these eggs, but not more. He proposes the hypothesis that the male eggs may not be viable.

Banta finds that the period of development in the egg chamber (entire period of embryonic development) is longer for male than for female young. Series of females that were known to be producing male offspring and others female offspring were observed at 10-minute intervals. From 1041 broods of young, at 20° C., the male broods spent an average of 40 minutes longer in the brood chamber than the female broods; *i.e.*, 2818 minutes in the case of the males and 2778 minutes in the case of the females.

SEX IN RELATION TO LENGTH OF ADULT INSTAR

Three events in the life of an adult female Cladoceran follow each other in the space of 5 to 8 minutes, *viz*, release of the young from the mother's brood chamber, ecdysis (molting) by this mother and ovulation into brood chamber. The interval between one ecdysis and the next following ecdysis is an instar. Now if eggs of a given sex are developing in the brood chamber, the length of the instar is constant, whether male or female eggs are forming in the ovary. But if in different females the developing eggs are of the same sex (say female) while the embryos in the brood chamber are male in some cases and female in others, then the length of the instar when male embryos are being carried is about three-quarters of an hour longer. (Result based on 335 broods.) Thus the time required for embryonic development rather than for egg ripening in the ovary determines the length of instar.

SCIARA

Studies on the control of the sex-ratio in *Sciara* have been continued by Metz and his group. It will be recalled that in some species or strains, called "monogenic," the progenies are unisexual; while in others, called "digenic," they are bisexual. Both types may occur in one species, and the strains of the two types are interfertile. Dr. Metz reports on further investigation of the significance of these two types.

"One of the most puzzling features involved in the monogenic type of reproduction, as noted in last year's report, is that which indicates the occurrence of selective fertilization. At its face value the evidence on this point seems to leave no alternative to the conclusion that selective fertilization occurs regularly here. Recently, however, cytological evidence has been secured which suggests the possibility of applying another interpretation to the case. The latter interpretation seems less probable than that of selective fertilization, and is brought forward merely because it calls for a suspension of judgment until the necessary additional facts are obtained. It is based on peculiarities in the behavior of the 'precocious' chromosome during the second spermatocyte division. These peculiarities suggest the possibility that an X-chromosome is regularly transformed into a Y-chromosome here by loss of chromatin, and that each sperm carries both an X- and a Y-chromosome. If this should prove to be the case, then the unisexual progenies would result, not from a selective elimination of sperms (selective fertilization) but from a selective elimination or inactivation of single chromosomes (X or Y). A thorough study of the 'precocious' chromosome, with the aid of mutant genes, will probably be required before this question can be settled.

INHERITANCE IN DIGENIC STRAINS

"In comparing sex determination in 'digenic' strains with that in 'monogenic' strains in *Sciara* it is necessary at the outset to recognize the fact that neither type represents the typical condition found in most animals. At first sight it might be thought that reproduction in the digenic lines is of the typical kind and that conditions in the monogenic forms represent modifications of this standard process. This, however, is not the case. Sex ratios in the digenic forms are not regularly 1: 1, but vary through a wide range in both directions (see earlier reports). Furthermore, the peculiarities of chromosome behavior during spermatogenesis in the monogenic type are common also to the digenic type.

"During the past year much work has been devoted (mainly by Dr. Monosmith) to genetic studies on the digenic race of *Sciara coprophila* which arose in the laboratory from a regular monogenic strain (see Year Book No. 28, p. 51). Although it is not certain that the digenic behavior of this race is identical with that of digenic species and races in nature, it seems probable that this is the case. If so, the results give strong indication that the monogenic and digenic types of behavior have a common fundamental background.

"Studies on the digenic race have been retarded by the fact that only two sex-linked mutant characters have been available for study, and that one of these is difficult to use. As they stand at present the results are as follows: (1) The digenic character of the progeny is determined by the female. (2) The characteristic arose, presumably, by mutation, although it has not yet been identified with any chromosomal gene. (3) As noted previously the digenic strain arose from laboratory stock and the original digenic female was genetically of the 'male-producing' type. Apparently the change which occurred is of such a nature as to make the eggs of male-producing females receptive to X-bearing, as well as Y-bearing sperms. (4) Many gynandromorphs and sex mosaics of various types occur in digenic progenies. (5) Digenic females appear to be mosaics arising not from a single egg nucleus fertilized by a single sperm, but from different combinations of nuclei. It is not yet certain whether different types of combinations may occur or whether the process follows one definite principle. Present evidence favors the view that more than one sperm enters into the fertilization and that more than one haploid nucleus in the egg is fertilized. To analyze the process adequately it is necessary to have at least three good mutant characters which may be used to identify the different X-chromosomes.

"These results support the hypothesis previously advanced, that the basic type of reproduction in *Sciara* is the monogenic and that the digenic type represents a secondary modification of this."

CHROMOSOME BEHAVIOR IN THE MONOCENTRIC SPERMOCYTE DIVISION

The general facts have been set forth (with illustration) in Year Book No. 25, page 39, and later reports. New studies show that the segregation of maternal and paternal chromosomes does not occur before the nuclear wall is broken down and the monocentric spindle figure is formed. All evidence supports the view that the chromosomes that are cast off actually move outwardly along radii from the single mitotic center, traveling in a direction just opposite to that followed by those that go toward the pole—and that they are *pushed* there. The hypothesis that the chromosomes are carried by streaming movements does not seem to be supported. Also, it is clear that the chromosomes which go to the two poles pass in close proximity while going in opposite directions. But observations on living material are required and planned for.

PIGEONS

RELATION OF METABOLISM TO SEX

Riddle has made further additions to his studies on this topic begun on pigeons and doves 20 years ago. He found then that the ova destined to produce males have a higher rate of metabolism than female ova and the higher metabolism of the male has since been revealed in humans, rats and fowl. Riddle, Christman and Benedict now find this true for the adult ring dove, as will be described in detail in the following section. The adult male dove has a normal metabolism which is about 3 per cent greater than that of the female. In doves, then, all stages—egg, embryos and adults—show the higher metabolism in the male.

"The demonstration this year," says Riddle, "of a differential response of the metabolism of the sexes to temperature supplies further cogent evidence that metabolic rate bears a *primary* relation to sex. The genetic composition of our various ring dove races varies considerably from race to race; and all these races vary enormously from the genetic composition of the various races of common pigeons. Notwithstanding all these divergencies the differential response within each race is (apparently) on the basis of *sex*—not some other characteristic.

"From 589 measurements made at 20° and 30° C. on males and females of 16 standardized races of ring doves it is definitely established that the metabolism of the male suffers a greater decrease with increase of external temperature than does that of the female. Between these limits the decrease in males is 28.1 per cent, in females 20.3 per cent. These values are further and fully confirmed by 167 measurements on 10 additional races, and by still other data.

"Under extreme (and abnormal) depression of the metabolism by a temperature of 30° C. the metabolism of the females is higher (7.6 per cent) than that of the males. At 20° C. the measurement of all of the three large racial groups indicates a higher metabolism in the male (3+per cent). Additional but preliminary measurements made at 15° C. similarly indicate a higher metabolism in males when measured at this temperature.

"The heat production of certain species and races—like that of the male sex—is much more depressed by a high external temperature than is that of other species or races. All races of common pigeons studied by us are much less affected than are the ring doves. Some races of ring doves—all of which races have been established on the basis of size of thyroid and pituitary—are much less depressed than other ring dove races.

"Measurement at these temperatures was preceded during 24 hours by maintenance at the same temperature, and with all the technique earlier found necessary to the accurate measurement of heat production in these animals.

"The measurements made at 30° C.—which is approximately the temperature that yields a minimum metabolism but with this varying somewhat for sex, race and season—supply evidence that such minimum values are obtained on birds in a non-physiological state. There is already some evidence that this applies to still other animals.

"This differential response of the normal metabolism of the sexes to temperature is of much consequence not only in metabolism studies, but in growth, vitamin and nutritional research, and in experimental biology generally. In accurate measurements very different results with the two sexes may be obtained merely through keeping the animals at, or temporarily subjecting them to, a high or low environmental temperature."

TABLE 3—*Basal metabolism and sex in adults; metabolism as related to environmental temperature in the sexes (ring doves); with percentage decline of metabolism per degree C. (values corrected for age) Data of Riddle, Christman and Benedict.*

Group	Sex	Number tests	Calories[1] at—			Percentage decrease of metabolism per degree C. between—	
			15° C.	20° C.	30° C.	15° - 20° C.	20° - 30° C.
16 races . . .	♂	287		3861	2777		2.81
	♀	302		3749	2989		2.03
10 races[2]. . .	♂	73		3862	2840		2.65
	♀	94		3756	3031		1.93
6 races[3] .	♂	107	4329	3824	2681	2.33	2.99
	♀	109	4210	3785	2932	2.02	2.25

[1] Small calories per 4 hours per 150 gram body weight.
[2] Additional races with fewer measurements.
[3] Measured at 15°, 20°, 30° C.

NUMBER OF RED BLOOD CELLS AND QUANTITY OF HEMOGLOBIN IN RELATION TO SEX

On this subject Riddle reports:

"The number of erythrocytes and the percentage of hemoglobin—the oxygen-carrying pigment of the blood—should both bear a relation to the metabolism of the individual and race. If metabolism and sex are related, the number of red cells and the quantity of hemoglobin should also be related to sex. These numbers and quantities may also be expected to vary with season, and with age, and with the stages of the reproductive cycle in females; also, differences in our 'endocrine' races are to be expected. All of these probable relationships are being subjected to an intensive study with the assistance of Miss Pela Fay Braucher. It will require another year to obtain sufficient data on our numerous dove and pigeon races and hybrids to bring this extensive study to a conclusion. The metabolism measurements now being simultaneously made on these same birds afford a strong support to this investigation. At present we shall report only upon the relation which the blood cells and hemoglobin seem to bear to sex difference.

"From 177 (duplicate) counts of erythrocytes made on 11 races of healthy ring doves it now appears that the males have about 2.3 per cent more red cells than females. Because of the considerable variation in these counts no race has been included in the calculation unless a minimum of 8 counts had been made upon it. Nearly similar restrictions apply also to the analyses for hemoglobin (Van Slyke method) reported below. On 6 races of common pigeons 130 counts indicate the males have 5.5 per cent more red cells. It is made practically certain that the pigeons have more cells per cubic millimeter of blood than do the doves. For the common pigeons, 3,534,000 (male) and 3,349,000 (female) are found; for ring doves, 3,288,000 (male) and 3,213,000 (female) per cubic millimeter.

"In 6 races of ring doves we find that the males have 7.07 per cent more hemoglobin than the females. In 5 races of pigeons a similar difference of 9.04 per cent is found. The pigeons, therefore, have more red blood cells and more oxygen-carrying pigment than the ring doves; and in both species the males have more cells and more of the pigment than the females. The actual values of hemoglobin in the two sexes of these two species—in grams per 100 c.c. blood—is approximately as follows: doves, 15.75 (male), 14.71 (female); pigeons, 16.50 (male), 15.14 (female).

"Thus our measurements on these two aspects of the respiratory mechanism of the sexes in two species of animals uniformly indicate the preparedness of the males for a somewhat higher rate of tissue oxidations."

ROTIFERS

Professor D. D. Whitney of the University of Nebraska was resident at this Department during the summer of 1929. He attempted to measure the rate of oxygen consumption of female-producing and of male-producing rotifer mothers, using *Hydatina senta.* In these rotifers an individual throughout life produces only a single kind of egg. Some of the mothers produce only diploid parthenogenetic eggs, which can develop only into female offspring. The other type of mother produces haploid eggs which develop into males, unless they are fertilized, in which case females are produced. Both types of mothers were used. A manometer patterned like Obreshkove's was used. It was found to be very sensitive; but with such microscopic organisms it is not surprising that prolonged effort will be necessary to eliminate disturbing factors.

PHYSIOLOGY OF SEXUAL REPRODUCTION AND DEVELOPMENT

ENDOCRINE STUDIES IN PIGEONS

The Physiological Standardization of Races—the Pituitary

Based on the evidence that pituitary size and function vary directly with intestinal length, Riddle has used intestinal length of pigeons as an index of pituitary size; since direct weighings of the pituitary gland of pigeons, though possible, involve a large error.

It appears that in the males of different races of pigeons there is a marked difference in mean intestinal length. Thus in Race NA it is 47.1±0.3 cm.; in Race N2 it is 56.9±0.6 cm. The difference here reaches 24 per cent. In 9 other races intermediate values of intestinal length were found. In general, the intestine is significantly shorter in the male than the female.

Riddle has also computed for 24 races the relation of body weight to intestinal length. The race with the largest intestine has a centimeter of intestine for each 2.60 grams of body weight; while the race with the shortest intestines has a centimeter of intestine for each 3.23 grams of body weight.

Again, the study of weight in relation to intestinal length in these races and 18 crosses between them shows that the intestinal length is inherited. For example, the two races with largest intestine, when crossed, give hybrids with the largest intestine of any of the hybrids and a weight-intestine ratio of 2.60 and 2.71 in the parent races and of 2.62 in the hybrid. Again where race 72 (♂ intest. length, 49.2 cm.) is used as a parent, the hybrids have extraordinarily short intestines. Riddle concludes that we not only have established races of doves with longer and shorter intestine, but have found the genetic factors governing intestinal length. Thus there is an inheritance of pituitary activity.

Does Thyroxin Enter the Egg During Oögenesis?

Riddle has found that in two sisters whose eggs required an extra 1 to 3 days for development, the thyroid glands were markedly under-active; while the eggs of their sisters with normal thyroids and normal metabolism hatched at the normal time. He suggests that this supports the view that "thyroxin normally enters the egg from the mother's blood and that the so-called normal incubation time of the bird embryo is contingent upon an adequate supply of thyroxin within the egg; an inadequate supply of the thyroid secretion results in a prolongation of the time required for the completion of embryonic growth."

Relation of Thymus Gland and Bursa Fabricius to Maturity and Reproduction

This subject has been under investigation since January 1929, in collaboration with Dr. J. Kříženecký and Miss Irene Polhemus. Thymus and bursa were removed at an early age and the satisfactory nature of the operation determined by re-operation 3 or 4 weeks later. First, it did not appear from these experiments that the time of sexual maturity was influenced by the operations. Second, the surprising result, opposed to earlier findings of Riddle, was obtained that some of these birds laid normal hatchable eggs—and not only those with abnormal egg envelopes. It is now obvious that the functions of thymus and bursa still remain in many respects enigmatic.

Effect of Section of Efferent Duct on Kidney and on Gonad

Incidental to surgical operations for the removal of certain endocrine organs, Riddle and his collaborators (Tange, Kříženecký, Polhemus) have sometimes cut or torn the ducts which lead from the kidneys and from the sex glands. Riddle has made a study of cases of this kind which have occurred during the past 10 years and published the following conclusions concerning them:

"Atrophy, partial and complete, of the kidney of dove or pigeon can be obtained by section of one ureter. Pressure develops in the occluded duct and kidney, and insoluble urates later disappear from the contents of the duct. The uninjured kidney readily undergoes functional hypertrophy.

"These observations have a bearing on the problem of the agenesis of organs. They indicate that, in some cases, the absence of a glandular organ which, like the kidney, is functional in the embryo may actually form and—through malformation or malfunction of its duct—later undergo complete atrophy (not agenesis). In contrast, section of the genital ducts of these birds was not followed by atrophy of testis or ovary; this evidence, therefore, indicates that the absence of gonads in birds (true agenesis) has a different origin and significance."

RÔLE OF THYROID AND THYMUS GLANDS IN DEVELOPMENT OF PIGEONS AND DOVES

Dr. Jaroslav Kříženecký, working with Riddle and using his Columbid material, reports:

"In the thyroid gland of Columbids no typical cyclic changes in structure were found at the various phases of the cycle. During ovulation the gland probably increases the size of the cells; but the great racial variability in the general structure of the gland makes this uncertain.

"In baby chicks the administration of thyroid hormone accelerates the rate of feather production; but in pigeons, owing to the naturally rapid rate of feathering, the treatment must begin earlier—on the day of hatching. The dosage must be small (under 0.02 gram) and the effect is much weaker than in fowl.

"The influence of the thyroid hormone on the rate of replacement of the large wing and tail feathers of ring doves was tested by measuring the time of replacement after pulling them out on one side of the body of control birds, then giving about 0.01 gram thyroid substance daily to the bird and pulling out the feathers on the other side of the body. There was found a faster growth in all feathers during the period of treatment; but differentiation was completed prematurely before the feather had acquired the normal length.

"The growth curve of the developing feather was studied, both before and after eruption from the surface of the skin. It appears that the total growth cycle gives an S-shaped curve of growth—but an unsymmetrical one—since the first inflection occurs 170 hours after development of the feather begins, while the second inflection occurs about 12 days before growth ceases."

Kříženecký studied the relation between rate of growth of feather and its ultimate size. He concludes that the correlation is not high. Thus a wing primary 145 mm. long completes its growth in 37.6 days; while a short dorsal feather 25 to 30 mm. long requires 41 to 44 days. The structure and functions of the feather are important in influencing its rate.

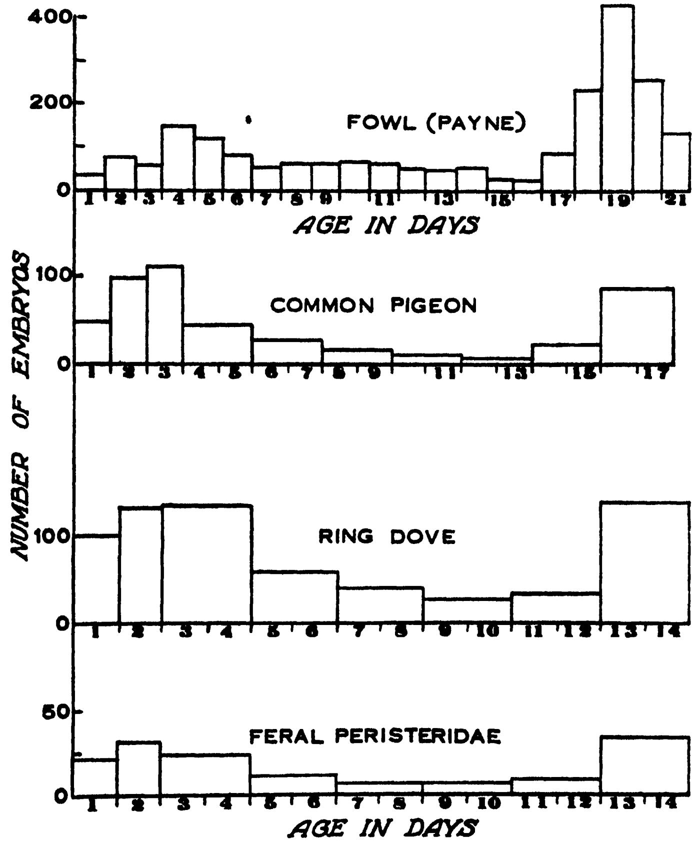
The "scraggly" pigeons that have developed in our pens were studied, and it was found that the absence of hooks and barbules that characterizes them is apparently associated with a premature keratinisation of the proliferating tissue of the feather follicle. The scraggly feathers grow irregularly and incompletely. Also thyroid-thymus treatment (per os) has no effect on the scraggly character.

Kříženecký had previously found that the decrease in body weight produced by administering dry thyroid substance per os can be reduced to about one half by simultaneously administering dry thymus. Since nucleic acid is present in large amount in the thymus, the hypothesis was tested that it, rather than the thymus hormone, is responsible for the result. After appropriate set-up it was found that thyroid alone reduced body weight 21 per cent; thyroid-thymus 12 per cent and thyroid-nucleic acid 27 per cent. Consequently, not the nucleic acid but the thymus hormone seems to afford the antagonism.

Age Distribution of Mortality in Bird Embryos

It has been found that dove and pigeon embryos tend to die in unusual numbers at two distinct parts—near the beginning and at the very end—of the incubation period. One similar study on the time of death of fowl embryos has earlier shown a similar tendency in that species.

AGE DISTRIBUTION OF DEAD EMBRYOS



Embryos of four kinds of birds die in excess numbers at two quite comparable stages of development.

Riddle has published his results on this matter which were summarized as follows:

"The age distribution of 2010 dead embryos, from three very distinct kinds of doves and pigeons, is figured and described. This age distribution in three newly studied groups, like that previously known in the common fowl only, shows two distinct peaks, or periods, of high death rate. Despite the variable length of the incubation periods of these four species the periods of maximum mortality occur at essentially equivalent pre-hatching stages in all cases; the death rate of the first period attains a maximum at the third or fourth day, and the maximum of the second period—irrespective of the total length of the incubation period—includes the final two or three days of incubation. These two peaks of prenatal mortality are, therefore, probably characteristic of avian reproduction generally.

"The excess mortality at these two periods seems to be only partially accounted for by the action of lethal factors and ordinary incubation conditions.

"It is suggested that an important part of the mortality of the first period is due to failures in respiratory adjustment. This suggestion is shown to be supported by a wide survey of facts obtained from many sources, and hitherto unconsidered in their relation to this problem.

"It is indicated that a notable share of the excess mortality that occurs immediately preceding hatching is ascribable to an inadequate water supply at this period. The many devices of the egg to obtain and to conserve its water supply are discussed.

"The building of each individual egg of the bird is an engineering problem—and each problem is executed separately. Usually the finished structure permits the success of complete development; more frequent failures attend the arrangements which should provide the prospective embryo with a suitable gaseous and aqueous environment.

"It is pointed out that the very device (thick shells) which is utilized by eggs to prevent water-loss—and avoid death in the final period—may too greatly affect respiratory exchanges and thus cause death in the early period. Many avian eggs are incompletely adapted vehicles of reproduction and some good and fit germs are unable to survive."

MICE

Hereditary Deficiency of the Pituitary Gland

Dwarfs occurred in a strain of Silver mice brought to us from England by Dr. L. C. Dunn. MacDowell has enlisted the interest of Dr. Philip E Smith, of the Department of Anatomy, College of Physicians and Surgeons, New York City. Dr. Smith found that in them the anterior lobe of the pituitary was deficient. MacDowell reports on this hereditary defect as follows:

"The deficiency consists of a complete absence of eosinophiles from the anterior lobe and at least a reduction in the cells of other types; the lobe appears to consist of a loose network of fibrous connective tissue. Other lobes of the pituitary are normal. In inheritance the defect is transmitted by normal parents; it is alternative with normal in its appearance. When present it leads to highly abnormal thyroids which in some cases are so defective as not to be recognizable as separate glands; it causes a marked reduction in the adrenal cortex and in the size of the gonads—leading to sterility; it causes a cessation of growth and of development at the end of the second week, at about 6 grams. After that there may be a slight and steady increase in weight due to accretion of fat, but the general appearance of the dwarfs is infantile, especially notable in the short muzzle and small ears. Snell has described the external features of this dwarfism and considers it to be a simple recessive Mendelian character.

"The causal relation between the defective pituitary and the other features of the dwarfs has been demonstrated by the Smith and Engle technique of daily transplants of fresh anterior lobes from rats. Within a week such treatments cause the dwarfs to grow at the rate of approximately half a gram a day. This continues until 18 gm. is reached when the rate slows down. Dr. Smith has given this treatment to eight dwarfs, seven of which have grown up. The eighth died on the sixth day without showing an increase of weight, but the endocrine restoration had been largely completed. Histological studies show that this growth is accompanied by complete correction of the thyroids, the adrenals and the gonads. Sexual maturity is manifest by the appearance of typical œstrous cycles, judged by vaginal smears and by the presence of corpora lutea and normal large follicles in the sectioned ovaries, as well as by copulations on the part of male dwarfs resulting in pregnancies. By all external signs these mice are normal in every way. However, histological examination proves that they are not normal mice since the deficiencies of the anterior lobe of the pituitary shown by the untreated dwarfs still persists."

Prenatal Mortality

The last stage in development is death. The period at which death occurs is largely determined by the nature of internal genetical factors. It has long been known that in mammals the developmental period sometimes ends early, even in utero. This result which MacDowell's discoveries on mice has emphasized has been carried forward by him with the assistance of Miss Jean M. Marsh. Over 250 early pregnancies have been studied by dissections and recovery of ova in the stages preceding implantation. MacDowell reports further as follows:

"At the end of the first day after insemination one division has taken place; at the end of the second day a second division has taken place, and sometimes a third, giving ova with four or eight cells. At the end of the third day the ova have reached the morula stage and occasionally the stage of the blastocyst. At this time they are usually found in the uterus. By the fifth day the implantation positions are marked by the uterine reactions which stand out clearly without magnification. Using as controls on the accuracy of the technique of recovery of ova the number of recent corpora lutea as well as the number of implants found in the five-day pregnancies, it was found that a considerable number of the one- and three-day ova were not recovered, but that the two-day ova were recovered within at least a few points of totality. This has been verified by a series of 50 pairs of sisters two days pregnant; one of each pair was used for recovery of living ova and the other for serial sectioning of the tubes. Since the number of implants found at five days fully equals the counts of the two-day ova, one might suppose there were no deaths during this period. But this raises the question as to how many of these five-day implants are due to really living embryos and how many merely uterine responses to dead or degenerative ova, which later appear as the small, dark-colored discs which have been taken as evidence of living ova that died after implantation. It seems not at all unlikely that the uterus registers the total number of ova that reach it in any condition. We have previously shown that the total number of implants living and degenerate, taken together, does not change from the seventh day to the end of pregnancy.

"The finding of zona pelucida without ova has been one of the surprising features of this study; such cases occur in the two-day pregnancies in about 12 per cent of all recoveries in fresh material.

"Whereas many litters are uniform in stage, more frequently considerable variation in the cleavage stage is found. This gives ample evidence of intra-litter variability, starting from the earliest stages and independent of the often invoked variation in the position in the uterus."

The Death of Pure Yellow Mice

It has long been known that a mouse bearing two doses of the gene for "yellow" dies before birth. MacDowell, working in Dr. L. C. Dunn's laboratory made a collection of 8-day embryos of yellow females, half of which had been mated with yellow and half with non-yellow males. A great excess of dead embryos was found from the matings between two yellows. From this it is concluded that the death of the homozygous yellow mouse occurs before the eighth day.

GENETICS OF SPECIAL TRAITS

MICE

Hereditary Eye Defects

This year two new eye defects have been discovered, making a group of four types that look much alike but differ genetically. One of these appeared suddenly and is transmitted to all offspring. The second appears in only about 10 per cent of the offspring of defective parents; it is associated with modifications of skull shape. Since, by selection, the incidence of eye defects in the young of the Bagg-albino line (upon which a report has been made earlier) has been raised to approximately 100 per cent, this strain has been crossed with several others, by Mr. T. Lanes, working under MacDowell's direction. It appears that the first generation hybrids are all normal in crosses with 3 distinct normal strains. When these hybrids are back-crossed to the pure-bred abnormal albino strain there are somewhat less than 50 per cent of abnormal-eyed offspring. The matter is being further studied. It is planned to trace the embryological history of these genetically controlled eye defects.

Leukemia

This major project of MacDowell is being carried out actively in collaboration with the Department of Pathology of the College of Physicians and Surgeons (where a group is working under the direction of Dr. Maurice N. Richter) with support of a second grant from the Carnegie Corporation. At Cold Spring Harbor, Mrs. Elsa B. Corbitt continues the experiments on the genetics of the susceptibility to inoculations of leukemia. During the year there have been bred 1674 individually pedigreed mice of the susceptible strain used in New York for inoculation experiments and 1707 mice (hybrids, back-crosses and pure-bred controls) used in the susceptibility studies at Cold Spring Harbor. The results so far obtained have been set forth in papers read and published or in course of publication.

The basal strains used in our work are: First, C 58, the leukemic strain, individuals of which succumb to leukemia as they approach the end of the first year. Few mice of this strain die from any other cause. Second, the Storrs-Little (StoLi) or non-susceptible strain, in which the disease does not develop even if the mice are nursed by mothers of the leukemic strain and kept in the same pen with leukemic mice all their lives.

The crosses between these two strains have begun to yield results. The occurrence of spontaneous cases among first generation hybrids indicates that susceptibility to leukemia is surely not a recessive trait. Since spontaneous leukemia appeared when the cross was made with the father from the leukemic strain, it is clear that the recurrence of the disease in successive generations is not due to maternal transmission of a non-genetic nature.

Biotypes of inoculated leukemia—The different lines of inoculated leukemic cells started from spontaneous cases show remarkable individuality. Four lines (A, E, H and I) that became established last year are at present in their 52d, 34th, 36th and 53d transfer respectively. In all lines the survival span after inoculation decreases successively after the first few transfers. Otherwise each line shows certain idiosyncrasies in such traits as: presence or absence of peritoneal and pleural effusions, a characteristic white cell count, either leukemic, normal or intermediate, the degree of infiltration of the liver and of the kidney, the presence or absence of an enlarged spleen, and finally constancy over long periods of the distribution of lesions, in contrast to variability.

These idiosyncrasies are clearly due to idiosyncrasies in the material (apparently cells) transmitted from mouse to mouse; these cells behave differently in the host-mice according to the nature of the donor-mice; they show their specific reactions irrespective of any organ-specificity in the host.

Nature of the Activating Material—As in independent organisms, this cellular material shows continuity of traits as well as changes; and an excellent opportunity is opened to study the causes, or at least the nature, of these changes. Obviously the requirements for propagation of the leukemia-inducing cells are very exacting, in that just the conditions found in the leukemic strain seem necessary, though tissue culture methods have failed to discover what these conditions may be. The highly uniform genetic constitution of the mice of the leukemic strain offers an environment that is genetically controlled. At the same time the inoculating material is directly available for experimental treatments in the course of each transfer.

If no agent in the inoculation separable from the cells themselves is discovered, the cause of continuity of traits and variations (mutations) probably lies in the chromosomes of the cells; at any rate the cytology of leukemic cells should early be studied. Such a study might throw light on the problem: What is the genetic relationship of the cells introduced by the inoculation and the cells removed from the hosts for the next transfer?

It may be added that the experiments of Dr. T. F. Zucker and Dr. S. Wilens, of the Department of Pathology, College of Physicians and Surgeons, in locating the factor responsible for leukemia support less the view of a virus than the view of the living cell.

Genetics of Susceptibility to Inoculations—Among our mice-strains is one that is completely susceptible (C 58) and at least one (StoLi) in which no inoculation (out of over 200 tested) has caused death from leukemia. Consequently it is possible to study the effect of changing the environment of cells from the same line by using as hosts crosses and back-crosses between the susceptible and non-susceptible strains. During the year the analysis of the genetic control of susceptibility on the part of the host mice has made considerable progress. The results are summarized in Table 4.

TABLE 4—*Summary of experiments to test the nature of hereditary control of susceptibility to inoculated leukemia*

Source of inoculant	Strain of mice inoculated	Result of inoculation		
		Died with lesions of leukemia	Survived	
			Lesions temporary	No lesions
Line I (28 exp'ts)..	C58	122	0	0
	StoLi	0	0	115
	F_1 (StoLi/C58)	127	0	0
	F_1 (C58/StoLi)	10	0	0
	F_1 C58	12	0	0
	F_1 StoLi	247	0	294
Line A (18 exp'ts)...	C58	56	4	0
	StoLi	0	9	52
	F_1	26	3	0
	F_1/StoLi	57	151	318

MacDowell discusses this table as follows:

"An experiment consists of the host animals inoculated with inoculant from a single donor; in making the tests of the different hybrid generations, mice from the resistant strain were usually included and both first generation hybrids and back-cross animals; the susceptible strain has always been included and used as donor for the next experiment, so that the material used for the tests was always carried by the same strain. The experiments with line I gave very consistent results; its constancy has been independently shown with the pure-bred susceptible strain. Through a series of 28 experiments it has consistently resulted in the death of all the inoculated mice of the susceptible strain (except those killed and used successfully as donors), but it has not produced death or lesions in any mice of the resistant strain; all the hybrids have been susceptible, and it should be noted that their susceptibility was transmitted through the father in most cases; slightly less than 50 per cent of mice from the back-cross of F_1 hybrids to the resistant strain have been susceptible; and mice from the F_1 hybrids crossed with the susceptible strain have all been susceptible. This proportion has run through the experiments and the numbers are sufficiently large to give this excess of survivors some meaning other than chance variation. If this is thought of in terms of genes, the excess does not approach the ratio of 1 : 3 expected from the interaction of two independent genes; if two linked genes are necessary to produce susceptibility and the excess of normals is due to cross-overs, a certain number of matings between survivors of inoculation should give susceptible young in the ratio of 1 : 3. Such matings have been made and susceptible offspring have been found, but it is too early to tell whether the interpretation of linked genes or normal overlaps or something else will be indicated. It will probably be necessary to make a full genetic test of all the mice in the back-cross by a second back-cross to the recessive strain, in order to determine whether the somatic ratio is really a genetic ratio. In this experiment the parents from the first back-cross could be tested by inoculation after a sufficient number of young had been bred.

"In contrast to the results from line I the experiments in which leukemic cells of line A were used show marked irregularity; at different times the proportion of susceptible mice in the back-cross varied from 1 : 3 to 1 : 127; these mice were from the same parents as the ones used in the experiments with line I. In spite of the variability in the ratios, in no case was there such a high proportion of susceptible mice as in the experiments employing line I. This difference in environmental requirements (host) for survival of leukemic cells is an additional indication of the deep-seated differences between the lines. Line I will grow in mice with a certain genetic complex; line A will grow only when a much rarer genetic complex is provided. Line I is constant; line A changes frequently so that at times one set of conditions is necessary while at other times the requirements are different. Differences of this nature between the lines are brought out only when the environment is varied, as in the case of a segregating back-cross.

"In general, line A, like line I, gave positive results with one strain, negative with the other, and positive with F_1 hybrids, but at certain periods when the proportion of back-cross animals that died was very low, some of even the pure-bred susceptible mice and some of the F_1 hybrids showed the signs and then recovered; furthermore, in a few cases, mice in the resistant strain showed signs of sickness and recovered. Whether these temporary signs mean partial susceptibility, or mean different things in different cases will have to be determined by special studies. They offer a suggestive approach to a therapy, since recovery from any form of leukemia is practically unknown."

Tail-rings in Mice

Dr. A. B. D. Fortuyn, who has long been interested in counting the number of tail-rings in rodents, during his brief sojourn here counted those of the inbred strain C 58 and StoLi strains and found an average of 172 and 205 respectively. The coefficient of variation was low in both cases—4.1 and 3.3 respectively. Since he had already found that from a mixed colony of mice the number of tail-rings may become nearly fixed by selection—the coefficient of variability being brought down from 6.6 to 4.4, Fortuyn concludes that the inbreeding has had the same result as selection. The F_1 hybrids between C 58 and StoLi appear to have an intermediate number.

RACING CAPACITY IN HORSES

Laughlin has continued his fundamental analysis of racing capacity in the thoroughbred horse. To make comparable the performance of members of this breed from different countries—in which the conditions under which a race is run differ—he has had to investigate the influence of the differential national environments on the same racing capacity. For this purpose the records were studied of 50 horses, part of whose racing careers had been spent in the United States and part in Great Britain; and others, as shown in Table 5, which gives the ratio of quality of performance of the same horses in the first country to that in the second country named.

TABLE 5—*Quality-of-performance ratios*

	Horses	Observed	Corrected
1. United States—Britain . .	50	1.0284	1.02675
2. United States—France. . .	40	1 0263	1.02775
3. United States—Germany. . .	0	(1.0305)	1.03030
4. Britain—France. . . .	49	1.0059	1.00105
5. Britain—Germany. . . .	23	1 0005	1.00340
6. France—Germany	47	1 0057	1 00245

It appears that, owing to superior conditions for racing in the United States, the same horses race about 3 per cent faster here than in Europe. The ratio United States-Germany could not be computed directly and so was obtained by means of a chain of relations; determined as 1.0305. By this same cross-checking the observations were corrected to self consistency with results given in the last column of the table. Laughlin reports further:

"In computing the racing capacity (*i.e.*, the Biological Handicap) of a foreign horse, he is first judged by American standard of performance as if running under American conditions. This tentative quality of performance, thus found, is then multiplied by the particular United States-foreign ratio. This, on the average, eliminates the matter of differential national environment as represented by different track nature (turf versus earth, etc.) climate, method of rearing, training, handling and riding.

"While we can not here separate entirely the influence of heredity from that of environment, in the production of racing ability, we can, in these cases, measure quite accurately the mean differential influence of two different national environments on the same heredity.

		Compared with the U. S. Standard, slowing down per cents in racing ability, i.e., in speed.
(a) Let the United States milieu constitute a standard with its influence on hereditary capacity rated at.	1.00000	
(b) The mean British environment slows down, on the average, the racing ability of the same horse to.	.97394	. . . . . . −2.606
(c) The mean French environment to. . . .	.97299	. . . . . . −2.701
(d) The mean German environment to. . .	.97059	. . . . . . −2.941

"These slowing-down percentages are the measures of difference of influence of national milieu (that is, the national complex of breeding, rearing, training, riding, race-management, track-nature and condition, climate, etc.) between the United States and the particular countries, on speed performance of the running horse; each is a Measure of Difference between two Environments."

METABOLISM IN RUNNING HORSE

Laughlin has spent much time and thought on the development of a mask for capturing a determinable fractional sample of the air expired by a running horse in a given time. The purpose of the device is to measure the comparative oxygen consumption of a given horse running under different conditions at different speeds and ages and of different horses running under like conditions.

Measurement of Performance

Laughlin has elaborated formulæ for interpreting the inter-compensation of distance run, weight carried, age and sex in relation to speed attained. These are as follows:

"1. Inter-compensation of Weight Carried and Distance Run, when sex, age and speed are constant.

"For example for colts, 3.75 years of age, when the best 'smoothed standard' or 'par speed' that the breed can produce in American horses, in a race truly run on a good or fast track, is 11.84 Mean Seconds per Furlong, the inter-compensation of weight and distance is measured by a parabola with the formula

$$d = \text{antilog}\left(\frac{4329.9706 - (W - 113)^2}{5519.2315}\right)$$

"2. Inter-compensation of Distance Run and Age, when sex, weight carried and speed are constant.

"For example for colts carrying 112 pounds, when the 'par speed' is 11.84 M.S.F., the inter-compensation of distance and age is measured by a witch-shaped curve with the formula

$$a = \pm\sqrt{\left(\frac{2.147366}{\log d - .634553} - 14.08596\right)} + 4.25$$

"3. Inter-compensation of Weight Carried and Age, when sex, distance run and speed are constant.

"For example for colts running 6 furlongs, when the 'par speed' is 11.84 M.S.F., the inter-compensation of weight and age is measured by an ellipse with the formula

$$W = \pm\sqrt{[49.00981 - 55.2542\,(a - 4.25)^2]} + 113$$

"Each of these formulæ is produced by substituting the constant factors in the one general formula

"M. S. F. for colts = f (Age, weight carried, distance run) previously reported."

Large Number Division by Calculating Machine

The computations on racing performance frequently involve large numbers. Laughlin has worked out a practical method of division of any number, however large, by means of the calculating machine; even when the divisor is greater than the direct capacity of the machine.

"The method is based on the principle that if in *all* required intermediate divisions the divisor will fit on the key board (*i.e.*, is within the divisor-capacity) the whole computation can be completed on the particular machine.

"The task then is to find a method which will call for no divisions not within the direct divisor-capacity of the machine.

1. $$\frac{a}{(b+c)} = \frac{a/b}{1+(c/b)} = \left(\frac{a}{b}\right)\cdot\left(\frac{1}{1+(c/b)}\right)$$

2. $$\frac{1}{1+(c/b)} = \left[1 - \left(\frac{c}{b}\right) + \left(\frac{c}{b}\right)^2 - \left(\frac{c}{b}\right)^3 \cdots \pm \left(\frac{c}{b}\right)^\infty\right].$$

3. Substituting (2) in (1),

$$\frac{a}{b+c} = \left(\frac{a}{b}\right)\cdot\left[1 - \left(\frac{c}{b}\right) + \left(\frac{c}{b}\right)^2 - \left(\frac{c}{b}\right)^3 \cdots \pm \left(\frac{c}{b}\right)^\infty\right].$$

"This calls for a separation of the divisor into sections 'b' and 'c.' Let 'b' consist of the left-hand digits to the direct divisor-capacity of the particular machine, followed by zeros representing the remaining digits. Let 'c' consist of the remainder of the divisor.

"Thus (3) calls for no divisor greater than 'b,' *i.e.*, the divisor-capacity of the particular machine. The first few numbers of this required series soon mount to a value beyond any conceivable need of accuracy; as the required number of terms in any case is readily determined. It being previously demonstrated that any two numbers, regardless of size, can be multiplied by a calculating machine of any limited capacity, and that a machine can divide any dividend howsoever large, by any divisor which is within the divisor-capacity of the particular machine, therefore, the present computation can be readily carried out on any machine."

HUMAN GENETICS

HEREDITY OF SEX-LINKED CHARACTERS

In other parts of this report sex studies in lower animals show the dependence of sex upon special chromosomes. The same dependence holds for man, also, and in man, as in *Drosophila,* there is a number of traits that are in inheritance linked with sex. A report on these sex-linked characters in man by Davenport is appearing in Genetics. The best worked out characters are color blindness, hæmophilia and opticus-atrophy. Other traits that appear in some strains to be sex-linked are: hypoplasia of white brain substance, night blindness or hemerolopia, myopia, megalocornia, pseudo-hypertrophic muscular paralysis of Gowers, coloboma, nystagmus, micropthalmia, ichthyosis, webbed toes, toothlessness, deficiency in sense of smell, wanderlust or nomadism. Where so many genes have been located with more or less certainty in the sex chromosome, crossing-over is to be looked for. Crossing-over is hardly to be looked for in the male and yet it is chiefly the male that reveals these sex-linked traits. A family of bleeders has been found which shows also color blindness; but no individual showed both traits. Such a union of two sex-linked traits (hæmophilia and color-blindness) has been found by Madlener in Germany but without crossing-over. In a family with night-blindness and myopia, described by Newman, there is no evidence that "crossing-over" occurred in the formation of the ripe eggs. Owing to the skipping of generations in sex-linked inheritance there is difficulty in tracing the incidence of sex-linked traits in a family. This difficulty emphasizes the need of a depository of family history such as the Eugenics Record Office had the ambition to meet.

HEREDITY OF OTOSCLEROSIS

A preliminary report has been made to the Committee on Otosclerosis on the data collected by Dr. Bess Milles on 100 families affected by otosclerosis. This dealt with the offspring of two parents both of whom were affected by otosclerosis. In seven families the designated combination was found. Of all 7 matings all the children (about 20) except one son, who had reached the age of incidence, males and females, exhibited the symptoms of otosclerosis. This approached expectation on the assumption that otosclerosis depends on a simple recessive defect; but a review of the literature on the subject suggests that there are various biotypes of otosclerosis and that the defect may be due to more than one recessive factor.

HEREDITY OF MENTAL TRAITS

Banker has adapted his SAI to render it applicable to higher institutions; and its efficiency is being tested. The work of testing involves a laborious computation of school data from various sources. This modified formula is now being utilized in the computation of SAI's from high school and college students.

"The first object is to work out such data with respect to the Huntington High School and compare the results with that obtained previously for the same students in the grades. Data formerly obtained at Swarthmore College has been supplemented by additional data for later generations and the plan is to compare the results obtained from this college with those obtained from the Huntington material."

MULTIPLE BIRTH RATE

In a brief paper on *Litter Size and Latitude* contributed to Ploetz' "Festschrift," Davenport calls attention to the fact that in rodents, as found in the reports filed at the U. S. Bureau of Biological Survey, the size of litter diminishes from North Canada to Southern California and Mexico. The multiple birth rate in humans also diminishes as one approaches the equator, from 2 7 per cent in Norway to 0.5 per cent in Ceylon. The hypothesis is suggested that the same factor or factor-complex that is responsible for large litters in northern latitudes among rodents acts also in the human species. Such a factor might be found in the shortness of the summers, and a possible selection in favor of twin-producing families in more northern regions.

PHYSICAL AND MENTAL DEVELOPMENT

With the aid of Miss Blanche M. Minogue, psychologist at Letchworth Village, New York, the director has obtained both physical and mental measurements continued for 6 or 7 years on 78 boys, mostly of Nordic stock, at an institution for feeble-minded. The intelligence quotients ranged from 13 to 94; for the most part were in the 50's, 60's and 70's. A physical age was worked out by a new series of standards. Among the conclusions drawn were the following: The correlation between physical and mental development is about the same as that between stature of brothers—about 0.50. Mental development is only one phase of general bodily development, just as physical development is. The physical and intelligence quotients tend to decrease slightly with age.

GENETIC CONSTITUTION OF THE AMERICAN POPULATION

Population Movements in Pan America

The settlement within historic time of the two great continents of the New World afford a unique opportunity to study the relation of kind of population to achievement. The interest of the Pan-American Union and its agreement to collaborate especially in Spanish America has been secured and the Eugenics Record Office will assist in organizing the study. This work is being undertaken by Laughlin.

It is proposed to secure data on and to analyze the movements in population in relation to causes and consequences, by number, cultural level, race, and inborn quality in the several countries of Pan-America since the discovery, with the view to determine more definitely than is now known the nature and controllability of specific factors in population change.

Eugenical Sterilization

Laughlin, whose book on sterilization is recognized as the standard, is frequently importuned to make further studies in this subject. During the year he has published (as a supplement to the Annual Report of the Municipal Court of Chicago, 1929) a paper on the *Legal Status of Eugenical Sterilization.* This work is described by Laughlin as—

"an examination of litigation under the Virginia Sterilization Statute, which Statute was finally and definitely upheld by a decision of the Supreme Court of the United States. This decision was found to mark an important advance in the establishment of the eugenical authority of the state In this development the end sought was the prevention of hereditary degeneracy by a method sound from the legal, eugenical and humanitarian points of view. It is important from the standpoint of eugenics that, in reaching this position, the nation in its experimental development of eugenical sterilization followed the scientific method of trial and error, in which the several states were the experimental units. It is now possible for any state, if it desires to do so, to enact a sterilization statute which will be well adapted to its purpose and which will be upheld by the courts of the particular state and of the nation as being well adapted to its desired end, to providing due process of law, and to giving the equal protection of the law to all subject individuals.

"The second study was brought down to May 1st, 1930, and has analyzed the legislative, court and administrative record of eugenical sterilization in the United States and Canada. It shows a clarification on the part of the several states as to the purpose, possibilities and limitations of eugenical sterilization, and an improvement in the administrative technique including the evaluation of genetical evidence for determining hereditary degeneracy."

ADMINISTRATIVE RECORD

The combined libraries of the two sections of the Department as of June 30, 1930, comprised 13,282 books. In the archives of the Eugenics Record Office were 1983 books, 9030 field reports, 33,247 sheets in special trait files and about 13,790 "Records of Family Traits." We have received during the year over 2000 sheets of various other schedules and much printed biographical and genealogical material in the form of clippings. Some 30 collaborators, mostly from educational institutions, have sent in collections of "Family Records."

GEOPHYSICAL LABORATORY[1]

ARTHUR L. DAY, DIRECTOR

THE EFFECT OF HIGH PRESSURES ON BINARY SYSTEMS[2]

In the language of physical-chemistry, equilibrium, that is, the condition of stability of the various phases which may appear in a system of one or more components is primarily dependent on the three factors, temperature, pressure, and composition. A vast amount of experimental work has been done on systems in the limited region around room temperature and atmospheric pressure, but only in recent years has effective progress been made at high temperatures; and in the field of high pressures only a beginning has thus far been accomplished.

A complete study of a system (*e.g.* a mineral group) involves an investigation of its behavior under all possible temperatures and pressures. In actual practice the usual procedure is to take the three variables, temperature (t), pressure (p), and composition (x), two at a time. Some results of considerable interest and importance have already been attained, both at the Geophysical Laboratory and at one other institution, on the effects of very high pressures on systems of one component with p and t as the variables, although they are much less comprehensive than for the t-x relations. We have now been able for the first time to work out in detail a system of two components under pressures considerably above 10,000 atmospheres and to draw a diagram with p and x as the variables, thus affording some notion of the appearance of p-x diagrams under extreme pressures.

The systems of primary interest to us are those approaching silicate magmas in composition; but in starting a new line of investigation it is the wiser plan, and sometimes the only practicable one, to begin with a simple system of which many of the properties are already known. It is also advisable to begin with low temperatures, as was done in the first physico-chemical investigation of t-x relations. We have chosen to begin with the system $NaCl$–H_2O at 25°, and in the figure are shown the conditions of equilibrium, at various pressures and concentrations, in this system. The several equilibrium lines divide the whole region into eight fields within which various pairs of phases are in stable relation.

This diagram presents some interesting and surprising features. The curve at the left is the freezing-point line of ice-VI (the stable solid form of water at 25° C.). The curve starts (left) at 9630 bars (or c.g.s. atmospheres), which is the freezing pressure of pure H_2O, and increases continuously with the concentration until it intersects the solubility curve of NaCl at 16,750 atmospheres and 25.3 per cent NaCl. This solubility curve has a peculiar form. At low pressures the solubility of the salt increases with pressure, but the rate of increase falls off at higher pressures and the solubility reaches a maximum at 4000 atmospheres, where it has increased from 26.4 to 27.6 per cent; above this maximum the solubility decreases with increase of pressure. At 8000 atmospheres $NaCl.2H_2O$ becomes the stable solid phase and since the inversion temperature also passes through a maximum at 9800 atmospheres above which the temperature falls, at 11,800 atmospheres anhydrous NaCl again becomes the stable phase (at 25°). These two inversion points appear as small but abrupt changes of direction on the solubility curve in the present diagram. Beyond 11,800 atmospheres the solubility decreases continuously until the curve intersects the freezing-pressure line of ice-VI at what may be termed a pressure eutectic. At this point three phases are present, two solid and one liquid, hence in a 2-component system we have an invariant point similar to an ordinary eutectic on a temperature-composition diagram. When the volume of a mixture of NaCl and H_2O in any proportions is decreased at 25° the pressure will remain constant after it reaches 16,750 atmospheres until the mixture has completely solidified, provided that equilibrium is always maintained.

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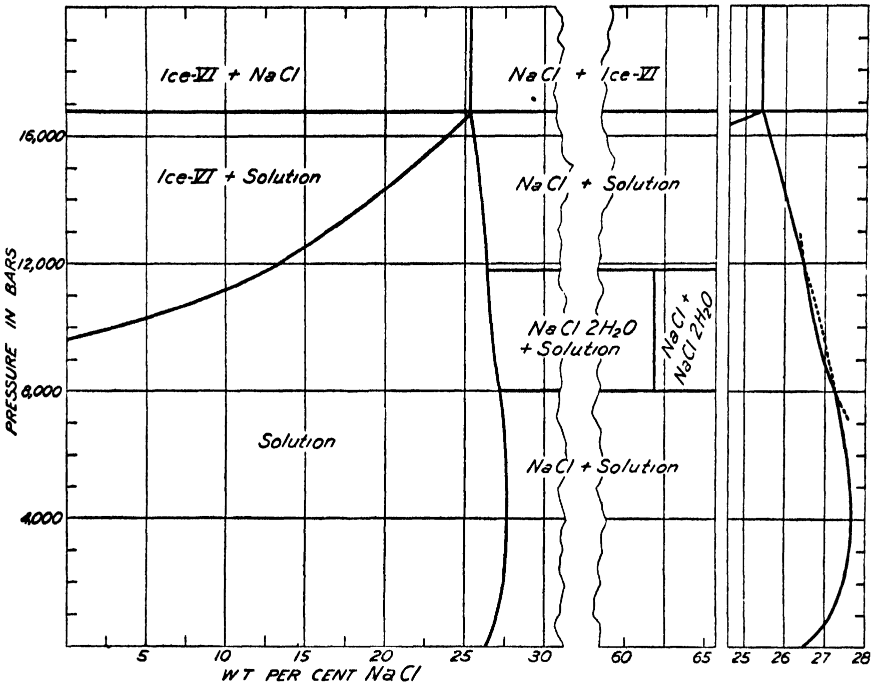
[1] Situated in Washington, District of Columbia.

[2] L. H. Adams.



Pressure-concentration diagram for the system NaCl-H_2O at 25°.

There are two other invariant points in the system where the solubility curve changes direction, analogous to incongruent melting-points on a *t-x* diagram. The remarkable feature of these two invariant points is that at both of them we have present *the same three phases.* This is made possible by the fact that when the temperature of the incongruent melting of NaCl .$2H_2O$ is plotted against pressure, the curve exhibits a maximum. An analogous situation in an ordinary melting diagram (*t-x*) is not known, but would exist, if a substance were found which, when heated at constant pressure, first melted and then at a higher temperature became completely solid again.

If a mixture containing 27½ grams of NaCl and 72½ grams of H_2O is subjected to increasing pressure, an interesting sequence of events will occur. At first the solution will dissolve more salt, since initially the solubility increases with pressure. At 2300 atmospheres all the solid will have disappeared (supposing always that the system remains in equilibrium) and from 2300 atmospheres to 6250 atmospheres the system will consist solely of homogeneous solution, but at the latter pressure solid NaCl will begin to crystallize out again in increasing amount. Upon further increase of pressure to 8000 atmospheres the solid NaCl reacts with H_2O to form $NaCl.2H_2O$, which at 11,800 atmospheres breaks up to form NaCl again. The solubility here continues to decrease, causing solid NaCl to increase in amount until finally at 16,750 atmospheres the whole mass solidifies (still at 25° C.) to a mixture of NaCl and ice-VI. The line representing the increase of pressure with this constant composition has crossed 5 of the 8 fields in the diagram, and the changes which have taken place may be represented diagrammatically as follows: NaCl + Soln. $\xrightarrow{2300}$ Soln. $\xrightarrow{6250}$ NaCl + Soln. $\xrightarrow{8000}$ $NaCl.2H_2O$ + Soln. $\xrightarrow{11800}$ NaCl + Soln. $\xrightarrow{16750}$ NaCl + Ice-VI. We have here a convincing demonstration that, contrary to what has sometimes been thought, significant and most important changes of state may be produced in a system *by pressure alone.*

It is instructive to compare a pressure diagram, such as the one shown here, with the more familiar melting diagram in which temperature is variable and pressure constant. Both consist of freezing-point—solubility lines which meet at eutectics and other invariant points and which, together with other lines parallel to the coordinate axes, divide the diagram into fields in which various combinations of phases are stable. Indeed, the two kinds of diagrams will be found to be quite similar in appearance also, except that the pressure diagram appears upside down. This is because, in general, *increasing* pressure produces the same kind of effect as *decreasing* temperature. For example, materials freeze when the temperature is lowered and, as a rule, when the pressure is raised. Furthermore, the addition of another material to a pure substance usually lowers the freezing-temperature but raises the freezing-pressure. This is equivalent to the statement that the solubility normally increases with temperature but decreases with pressure.

A comparison of the methods used in high-temperature and high-pressure investigations with multi-component systems also shows some similarities, as well as some differences. For both cases direct and indirect methods may be used. In the direct method, a melting-point or other transformation is observed more or less directly, either by visual observation or by measuring some change which is directly associated with the melting-point. Thus, the well-known quenching method may be used in high-pressure investigations as well as in high-temperature research. The familiar heating-curve method also has its counterpart in the change-of-volume method for determining the freezing-pressure.

In the practical application of the *indirect* methods, however, we find less similarity. It is now well known that the temperature of various transformations may be determined without actually causing the transformation to take place. Provided only that the phases whose relative stability we wish to investigate have been identified, the measurement of certain thermal quantities enables us to calculate the inversion-temperature. It so happens that in practice the relative ease of determining the thermal quantities with the requisite precision and of measuring the transformation-point directly is such that very little use has been made of this indirect method. For the investigation of systems under pressure the situation with respect to the corresponding indirect method is very different, for this reason: The fundamental quantity with which we are dealing when we measure thermal effects is entropy, and for pressure effects the exact analog is volume. Now, volumes and volume-changes are capable of direct measurement with a high degree of precision, and from a knowledge of the volumes we may calculate the relative stability of the various phases and the freezing-point—solubility curves, in most cases with greater ease and higher accuracy than we can determine them directly.

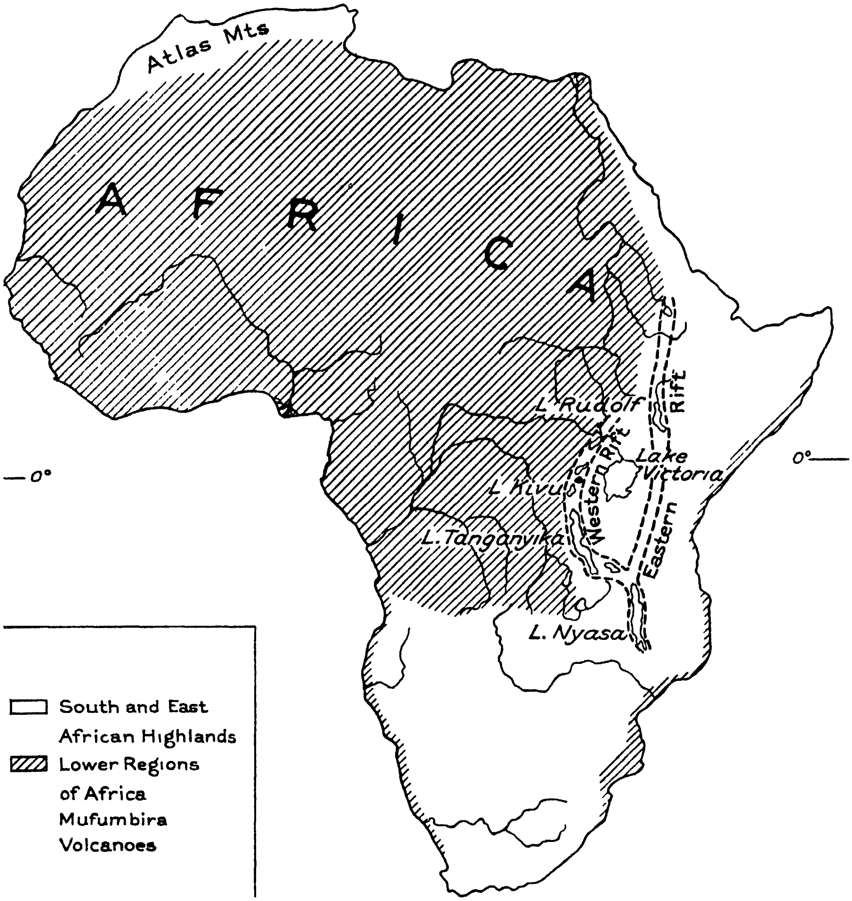
The stability of a substance over a range of pressures and at constant temperature depends upon the value of μ, the chemical potential (or of the derived quantity, activity) for that substance. For a pure substance the change in the chemical potential with pressure (at constant t and x) depends solely upon the pressure and the volume, a small increment of pressure causing an increase of μ equal to the specific volume multiplied by the increment of pressure. For any component in a solution, a similar relation holds except that instead of the specific volume we use a related quantity, the fictive volume or apparent volume of the component in the solution. Since the fictive volumes may be determined readily from the densities or specific volumes over a range of concentrations, it is evident that a knowledge of the volumes of the solutions over the desired range of pressures and concentrations is sufficient to enable us to work out the equilibrium diagram provided the stability relations at atmospheric pressure are already known.

In determining the boundaries of the various fields in the pressure-concentration diagram here presented, both the direct and the indirect methods were used with gratifying agreement, but more work was done with the indirect method on account of its many inherent advantages, not the least of which is that it affords the possibility of a moderate extrapolation with safety. This is because all the relations for a solution become much simpler at high than at low pressures. For example the fictive volume of NaCl in NaCl solutions between 0 and 25 per cent, at atmospheric pressure, changes from 0.2914 to 0.3991 but at 10,000 atmospheres the variation over this range of concentrations is only from 0.4372 to 0.4581. In general the course of the volume-differences becomes very regular at extreme pressures—abnormalities, which may exist at low pressures, have disappeared. The highest pressure at which any measurement in this system was made is about 13,000 atmospheres, but the extrapolation to over 16,000, not of the freezing-points themselves but of the quantities from which they were derived, is made with entire confidence.

Investigations in this field give promise of most interesting developments. Sufficient work has already been done to point the way toward further necessary research and, incidentally, to demonstrate the material advantages of the indirect, thermodynamical method for the study of multi-component systems at very high pressures.

VOLCANOES OF THE AFRICAN RIFT ZONE[1]

It has long been recognized by geologists that igneous activity, including volcanism, is intimately connected with movements of the crust of the earth such as faulting and folding. The exact nature of the connection is by no means well understood and any region of the earth which has experienced crustal movements that are recent and therefore the more readily decipherable, and which is at the same time a region of active volcanoes, has many natural advantages for the study of this fundamental question. The highlands of Africa with their Rift Valleys combine these characters in an eminent degree. The faulting which has given rise to the Rift Valleys is of recent date; indeed is believed to be still in operation. The character of the faulting and the nature of the forces that have brought it about



Outline map of Africa showing the Rifts.

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[1] N. L. Bowen.

should therefore be more readily discernible there than in areas where such activity is confined to the more remote past. In the same region there are many volcanoes, among them some of the loftiest volcanic piles on the face of the earth. Here, then, is a portion of the earth that we may hope will yield some of the fundamental secrets of volcanism, the only disadvantage being its vastness and its comparative inaccessibility.

A reconnaissance of the Rift Valleys of Africa during 1929 was under contemplation by Dr. Bailey Willis as a continuation of his studies in comparative seismology sponsored by the Carnegie Institution of Washington. His problem is concerned principally with crustal movements and the forces that bring them about. By way of extending these investigations to include observations of the volcanoes and their lavas, and thus laying the foundation for a cooperative study of the relation between volcanism and crustal movements, it was decided that Dr. N. L. Bowen of the Geophysical Laboratory should accompany Dr. Willis. Plans had already been made that Dr. Bowen should attend the International Geological Congress in Pretoria as the delegate of the Carnegie Institution of Washington. These plans were put into effect. Dr. Bowen attended the formal sessions of the Congress where he was appointed Chairman of the Section of Magmatic Differentiation and after the sessions participated in some of the excursions to localities of special interest to igneous geology. He then joined Dr. Willis to carry out with him the cooperative reconnaissance, the purposes of which have just been outlined.

The reconnaissance took them northward through Central Africa along the course of the Western Rift Valley which is, indeed, the main artery of north-south travel in Central Africa. The Western Rift is an elongate strip of country of much lower elevation than the highlands that bound it on either side. In it lie the great lakes of which Tanganyika is typical. In these respects the Rift is like any other valley, but upon closer acquaintance it is found that this colossal structure has been formed as the result of a fault-system of a general arcuate trend, corresponding with the arcuate form of the Rift (see accompanying map). The fault system is horizontally coextensive with the Rift itself, extending for many hundreds of miles. In addition the vertical displacements involved are very large. The highlands immediately adjacent to Lake Tanganyika rise abruptly to an altitude of some 4000 feet above sea-level whereas the bottom of Lake Tanganyika is more than 2000 feet below sea-level. We are here concerned with a great gash in the face of the continent. Ordinary erosional valleys can not have their floors lower than sea-level unless glacial scouring is involved, and here such action is not to be entertained. Even if there were no evidence from structural details, there is thus ample evidence from surface forms alone of extensive vertical movements of the earth's crust upon a fault-fracture system that extends through several degrees of latitude.

In spite of this extensive fracturing, it is noteworthy that volcanism has occurred only in a very restricted area along the course of the Western Rift. Typical volcanoes occur only near Lake Kivu in the Mufumbira area (see map), which is but 35 miles long. Here they are definitely associated with a series of cross faults that intersect the main Rift faults. There is a somewhat more extensive area nearby in which explosive action of volcanic origin has occurred, but, even including this, volcanism in association with the Western Rift is decidedly a minor feature.

Nevertheless the small group of Mufumbira volcanoes affords the best opportunity in Africa for the study of active volcanism. Two of the eight great cones in this area are in an active phase and one of them, Namlagira (10,046 feet) exhibits gaseous, explosive activity only in minor degree, so that it was possible to study its crater at close range. In the crater it was found that "boiling" lava fountains were playing in lava lakes whose activity is analogous to that of the lava lake, Kilauea, in Hawaii.

After the study of the Western Rift the "safari" turned eastward to examine the Eastern or Great Rift Valley. Between the Western and Eastern Rifts the African plateau has suffered a down-warping which has given rise to the basin of Lake Victoria. Some of the volcanicity immediately to the north-east and east of the lake, attaining its most impressive surface expression in Mount Elgon, may be regarded as connected with fractures formed during this warping of the crust.

The Eastern Rift is a surface feature analogous to the Western Rift, but much more extensive. The fault system which has given rise to it extends, with no more than minor interruptions, from the southern end of Lake Nyassa northward across the great plateau of East Africa, passes Lake Rudolph and apparently crosses Abyssinia into the Red Sea. The valley of the River Jordan and of the Dead Sea in Palestine is regarded by some investigators as an extension of the same structures. Nearly everywhere along the course of this great fracture system volcanism has occurred. Volcanoes have been built up in the Rift Valley itself, which, locally, has been almost filled with the products of their eruption. Volcanism is, however, much more wide-spread than the Rift Valley. Upon the bordering plateau great lava floods have been poured out and lofty cones have been formed, among them Kilima Njaro, the highest peak in Africa. This volcanism is, in many cases at least, associated with fracturing that occurred during the same long period wherein the Rift Valley was formed, and the fractures are no doubt to be referred to a common cause.

It will be plain from the foregoing discussion that the common, though by no means universal, association of volcanism with crustal movement is a demonstrated fact for the region of the African Rifts. More than this, it is possible that crustal movement exerts a control not merely over the existence of volcanism but also over the intimate chemical character of the lavas formed. The geologist knows, for example, that in certain regions of the earth all of the volcanic rocks, though there may be a considerable variation among individuals, show the common character of a richness in soda. In other regions they are rich in potash and in yet others in lime. There is a growing tendency among geologists to entertain the hypothesis that these chemical differences are associated with different kinds of earth movement. Highly sodic rocks, for example, seem to occur commonly in areas that have suffered tensional stresses with consequent down-faulting. The rocks of the Great Rift Valley of East Africa are found to be rich in soda and the crustal movements have been of the kind that result from tensional stresses. For this area, then, the requirements of the hypothesis seem to be met.

In the Central African Rift the volcanic rocks are for the most part of a distinctly different character. Here they are rich in potash and here, according to certain indications at least, the earth movements have been the result of compressional stresses. If these indications should be substantiated we have in this great region different types of volcanic rocks associated with different types of crust movement. It is, however, too soon to make definite statements. The whole problem must be viewed in the light of the completed study of the rock types collected, the significance of (apparently) minor exceptions must be evaluated and even then it may be necessary to suspend judgment pending further accumulation of facts.

PROBING THE DEPTHS OF YELLOWSTONE GEYSER BASIN[1]

The site selected for the drilling operations was in a nearly level area of wide extent, several hundred feet westerly from Old Faithful Geyser. This flat area or plain is shown by superficial excavations at nearby points to be the top of a series of beds of gravel and sand which probably underlie nearly the whole area of the Upper Geyser Basin. At numerous places in the neighborhood of the drill site there are pools of steaming or even boiling water, at some of which occur periodic overflows or phenomena of mild geyser activity. The area is plainly one in which the underground circulation of thermal waters characteristic of the geyser basin is vigorous, though not so intense as in the immediate vicinity of the greater geysers. The drill hole itself was begun in a deposit of siliceous sinter which covers the surface for hundreds of feet in every direction.

This sinter, in pure form, was found to be quite superficial, having a thickness of probably 15 feet. There was no definite lower limit, but pebbles began to appear, and the proportion increased with depth. At 40 feet the core consisted essentially of gravel cemented with opaline silica.

From here to a depth of 220 feet from the surface, the drill continued to penetrate a series of firmly cemented gravels and sands. The cementing material was predominantly silica. Near the surface this was in the amorphous (opaline) state, but with increasing depth it was succeeded by quartz, usually in minutely crystalline condition, but in places in easily recognizable crystals. Other secondary minerals readily determined were calcite and the zeolitic mineral analcite. Chemical analyses of the core material show it to be decidedly enriched in places with potash, and this is believed to be present as secondary orthoclase in some of the minutely crystalline portions. Further analytical work, supplemented with microscopic examination, will probably permit the identification of other secondary minerals.

The original gravel of these beds was of rhyolitic composition, as might be expected from the character of the rocks surrounding the geyser basin, but the whole mass of material shows evidence of thorough soaking by hydrothermal solutions. The principal deposition of secondary minerals was in the interstices between pebbles, but the pebbles themselves have been somewhat attacked. In fact, some of the deeper beds have been so thoroughly altered that their original character would hardly be recognizable without the clue afforded by transitional types. In addition to these effects there are rather numerous small but distinct veins and crystal-lined cavities, which intersect the beds at various angles. These seams or cracks were evidently formed after the beds had become somewhat indurated, and must have resulted from slight movements, possibly caused by readjustments brought about by removal of material in solution. No evidence of real faulting was found.

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[1] C. N. Fenner, Arthur L. Day.

The depth which the gravel beds reach at this point is worthy of note. The elevation of the rock floor at the base of the gravel beds is here no higher and is probably even a little lower than the point at which the Firehole River, the main drainage stream, escapes from the Lower Geyser Basin over a rocky floor, eight miles to the north. If the gravel beds were removed a distinctly abnormal topography would be revealed. Though a positive statement can hardly be made yet as to the cause of this abnormal condition, the relations suggest overdeepening of the basin by glacial scour, acting upon rock surfaces decomposed and softened by previous hot spring or fumarolic activity. The gravel beds would then naturally be looked upon as deposits of redistributed glacial material.

At 220 feet the drill hole entered rock in situ. This was obsidian, which at this point was very little altered. At two other places lower in the hole, fresh-looking obsidian was passed through, which evidently represented "islands" not reached by the general circulation. In most places the rock was very greatly changed in appearance, much of it to such a degree that from appearance alone it would be impossible to say what was its original character. Analyses, however, show sufficient resemblance to the composition of obsidians and rhyolites to make it appear most probable that the original material was of this nature, and in places hints of an original structure (such as the perlitic structure of obsidians or phenocrysts of quartz and acid feldspar) survive in the altered material. It is somewhat surprising, however, that in these altered obsidians little or no evidence has been seen of lithophysæ or spherulites, structures which are very common in the obsidians of the Park and which would be expected to persist.

At these lower levels in the drill hole the new minerals formed do not appear to be of such variety as in the upper levels. Quartz is exceedingly abundant, both as a general replacement of the rock and in distinct veins. Calcite also is common, and aggregates of small crystals of chlorite. Secondary orthoclase is probably common, but in such minute development as not to be identified with certainty. Occasionally a little cluster of hematite scales is seen.

It is remarkable that alkaline waters carrying hydrogen sulfide in solution should have permitted the sesquioxide of iron to persist and to recrystallize as hematite, and equally remarkable that though sulfide ore minerals have been searched for with care, none has been certainly recognized. It has been generally accepted among economic geologists that the transportation and deposition of economically important sulfide ores have commonly been effected in hot solutions of alkaline sulfides, but though the waters here are of the general character regarded as appropriate, they have failed to produce the effects that might be expected. This might be attributed to lack of the required material at the source, or to improper conditions of temperature or concentration in the waters themselves. It is, at least, important to know that waters of the definitely determined characteristics that we have here have not produced any recognizable effects as regards deposition of ores. Of less economic importance, but of much geologic interest, is the positive information yielded regarding the conditions required for the transportation and deposition of certain silicate and carbonate minerals, and regarding the alterations in the chemical and mineralogical composition of the rocks traversed.

The hole attained a depth of 400 feet. Temperature measurements were made at short intervals throughout. Near the surface, water standing in the casing showed a temperature of 60°C.; at 400 feet the temperature was 180°C. Between these points there was a progressive increase, but with considerable local irregularity. There was fairly definite indication that the cracks and seams traversing the rocks, as revealed by the cores, offered channels through which cooler or hotter waters were able to circulate and gain entrance to the bore hole. An interesting relation is brought out by plotting the pressures of saturated steam at the temperatures actually found at various depths, compared with the hydrostatic head of a water column reaching from each of the corresponding depths to the surface. It is found that the two graphs nearly coincide. From the relations found it appears that the hydrostatic head is sufficient to hold down the steam pressure, but that if the head were slightly lessened in any manner the equilibrium would be destroyed and great quantities of highly heated water, which impregnate the gravels and rocks below, would quickly be converted, in part, into steam and would be ejected from the vent. It is easily seen that the energy and mechanism requisite for a geyser eruption are here available. What is not so readily perceptible is the mechanism that brings such an eruption to an end in a relatively short time. At the drill hole, as an experiment, the steam was allowed at one time to escape unhindered for about an hour. It rushed out with a heavy roar, and there was no perceptible diminution in the amount of wet steam escaping at the end of the period. It seems necessary to suppose that in order to produce intermittent geyser action the underground channels should be of such a character as, first, to restrict the escape of steam from lower regions within a short time; and, second, to permit the influx of large quantities of cold water after the first rush of steam is over, and by means of the condensation thus effected to suppress eruptive activity until the column is heated again to the proper condition.

Before the drilling was begun, considerable apprehension had been expressed by some of the Park employees that the geyser system of the whole neighborhood would be disastrously affected. Probably everyone is now convinced that there was no danger of such a result. The only apparent disturbance has been a little modification of the characteristics of some small warm pools immediately adjacent. When the work was begun, these pools appeared as small, sinter-lined basins, in which water stood at a constant level. Near the end of the work, two or three of them began to manifest a slow periodicity of action. At intervals of several hours the water rose and overflowed in considerable volume, and gas bubbles escaped; then the level sank again. In view of their proximity to the drill hole, and in consideration of the underground channels revealed by the boring, it is not surprising that some such effect should have resulted.

Although the drilling of this hole has not answered all the questions that might be asked, it has given information on a number of important matters and has suggested a rather different picture of the underground conditions in a geyser area from what has sometimes been held. Drilling will be continued in other hot-spring areas during the present summer (1930).

Brief reviews of the papers published by members of the Laboratory staff during the current year follow.

PUBLICATIONS

(690) The elastic properties of certain basic rocks and of their constituent minerals. L. H. Adams and R. E. Gibson. Proc. Nat. Acad. Sci. 15, 713–724. 1929.

The importance which is now being attached to the properties of basic rocks in inquiries concerning the nature of the deeper parts of the Earth's crust has made it seem advisable to carry out additional measurements of the compressibilities of these rocks and of their constituent minerals. Additional measurements of the compressibility of several diabases have been made with an improved apparatus, and the compressibility of the garnets, grossularite and almandite, and of the pyroxene, jadeite, have also been determined with a view to estimating the compressibilities of eclogites. The results demonstrate that at 15,000 bars and 30°C. the maximum velocity of longitudinal elastic waves through rocks of basaltic composition and mode is 7.4 km. per sec. The compressibilities of garnet and jadeite are of the order of that of steel, and consequently, despite the high density of these minerals, the velocity of longitudinal waves through eclogite is estimated to exceed 8 km. per sec. Existing data seem to place the possible components of the Earth below 60 km. and above the core in the following ascending order of probability: holocrystalline basalt, eclogite, peridotite.

(691) Mechanical, thermal, electrical, and optical properties of silica. Robert B. Sosman. International Critical Tables, Vol. 4, 19–22; 5, 105–106; 6, 341–344. 1928–1929.

Extracts from Volumes 4, 5, and 6 of the International Critical Tables.

(692) Dahllite from St. Paul's Rocks (Atlantic). Henry S. Washington. Am. Mineral. 14, 369–372. 1929.

The dahllite, a calcium phosphate, with OH and CO_2, occurs as thick masses filling cracks in the peridotite, where it was collected by the *Quest* Expedition (see No. 702). An analysis shows its resemblance to the mineral from other localities, and a general formula for the whole series is suggested.

(693) The Valley of Ten Thousand Smokes. I: The fumarolic incrustations and their bearing on ore deposition. II: The acid gases contributed to the sea during volcanic activity. E. G. Zies. Nat. Geog. Soc., Contributed Technical Papers, Katmai Series, Vol. 1, No. 4, 79 pp. 1929.

In this paper the incrustations found in the Valley of Ten Thousand Smokes are described, the determination of metallic constituents in the incrustations and in the new lava by means of a combined chemical and spectrographic procedure is given in detail, and the bearing of the incrustations and emanations on ore deposition is discussed. Special attention is drawn to the two factors involved in the rôle played by the acid emanations. Thus it is shown that the *intensity factor*, or concentration of the acid gases in the steam, controls in a large measure the amount of metallic halides, sulfides and oxides that can be transported in the vapor phase from a hot igneous intrusion to a cooler region. It is also shown that the *capacity factor*, or total amount of acid constituents emitted, determines (1) the amount of alteration of the rocks with which the gases come in contact, and (2) the amount of each acid gas that is contributed to the sea. It is further shown that the hydrochloric acid and hydrofluoric acid found in the emanations could not have been derived through impenetration of sea-water.

This paper also contains a discussion of the general physico-chemical factors that govern the transportation, deposition, concentration and selective reconcentration of the metallic constituents that were obtained from the new lava. It is further shown that even though no large ore body is likely to form in the Valley, owing to unfavorable drainage conditions, yet the total amount of heavy metals that have been transported as halides, sulfides and oxides in the vapor phase and the total amount of these metals that have been derived through attack of the pumice by the acid gases in the short period of seven years are so great that, in a favorable locality, large ore bodies could be formed in a relatively brief period of geologic time.

(694) The polymorphism of sodium sulfate. III: Dilatometer investigations. F. C. Kracek and R. E. Gibson. J. Phys. Chem. 34, 188–206. 1930.

With the help of an ordinary dilatometer and a dilatometer specially developed for studying volume changes under a pressure of fifty bars we have been able to confirm and amplify the results of the first two papers on the polymorphic transformations of Na_2SO_4 between 160° and 260°. These changes take place slowly and are accompanied by marked hysteresis when the salt is dry, but in the presence of water or a trace of H_2SO_4 the salt inverts promptly and rapidly. In consequence of the more accurate estimates of the transition temperature which we were thus able to make, we can assign to each modification the ranges of stability indicated by the following scheme where the figures below the arrows indicate the temperature of each change and the figures above are the volume changes in cm^3 per gram.

$$Na_2SO_4V \underset{160-180^\circ}{\overset{0.0005}{\rightleftarrows}} Na_2SO_4IV \underset{185^\circ}{\overset{-0.0034}{\rightleftarrows}} Na_2SO_4III \underset{241^\circ}{\overset{0.0070}{\rightleftarrows}} Na_2SO_4I$$

Na_2SO_4II has no region of stability at low pressures, but if the reaction $Na_2SO_4I \rightarrow Na_2SO_4III$ is inhibited the transformation of Na_2SO_4I to Na_2SO_4II takes place reversibly at 236°, with a volume decrease of 0.004 cm^3/g.

(695) The crystal structures of magnesium, zinc and cadmium ferrites. E. Posnjak. Am. J. Sci. 19, 67–70. 1930.

Powder diffraction data were obtained from magnesium, zinc and cadmium ferrites. The length of the edge of the unit cube containing eight molecules (spinel type) is for $MgO.Fe_2O_3$ 8.36±0.01 Å; for $ZnO.Fe_2O_3$ 8.41 ± 0.01 Å and for $CdO.Fe_2O_3$ 8.67 ± 0.01 Å. The calculated densities in the above order are 4.518, 5.349, and 5.835, while the direct determination resulted in the following values: $MgO.Fe_2O_3$ 4.481, $ZnO.Fe_2O_3$ 5.290, and $CdO.Fe_2O_3$ 5.764.

(696) The polymorphism of potassium nitrate. F. C. Kracek. J. Phys. Chem. 34, 225–247. 1930.

Studies were made on KNO_3, dry and moist, by differential thermal analysis to determine accurately the temperatures of inversion and the magnitude of the heat effects involved, and by means of a pressure dilatometer used at pressures up to 300 bars (b.), to investigate the volume changes on inversion and the change of the inversion temperatures with pressure. Three forms of KNO_3 occur within the region studied. The triple point is at $128.0_2°$ and 82 b. KNO_3I and KNO_3II are in equilibrium at $127.6_6°$ and 1 b., the reaction between these forms being reversible in presence of H_2O. In thoroughly dry salt the pressure modification KNO_3III appears metastably and is in metastable equilibrium with KNO_3I at 126.1° and 1 b. On heating, KNO_3II inverts directly to KNO_3I; on cooling, dry KNO_3I first changes to KNO_3III which then inverts to KNO_3II. Above 82 b. pressure KNO_3III has a stable field between definite temperature limits. Values are given for the volume changes on inversion and for the corresponding latent heats of the phase reactions.

(697) Pacificite, an anemousite basalt. Tom. F. W. Barth. J. Wash. Acad. Sci. 20, 60–68. 1930.

Microscopic investigations of the undersaturated lavas of the Pacific island volcanoes have shown that there occur certain purely feldspathic basalts, without nephelite and usually with olivine, the analyses of which show the presence of considerable amounts of nephelite in the norm. It has been shown, however, that what is apparently a normal plagioclase is in reality anemousite (plagioclase with carnegieite in solid solution). We have consequently in these lavas a rock that under other conditions would have contained very considerable nephelite (corresponding to basanites and tephrites), whereas this molecule actually enters a triclinic plagioclase. The name *pacificite* has been proposed for this group of anemousite basalts.

(698) Vapor pressures of solutions and the Ramsay-Young rule. Application to the complete system water-ammonia. F. C. Kracek. J. Phys Chem. 34, 499–521. 1930.

The Ramsay-Young rule (of which the Dühring rule is a special case),

$$(T_A/T_B)_p = (T_A/T_B)_{p_0} + c\,(T - T_o)_B,$$

is derivable from the better known logarithmic vapor-pressure formula

$$\log p = A/T + B \log T + \cdots + I.$$

The rule lends itself more easily than the latter formula to the study of the boiling point (or conversely, vapor-pressure) relations for solutions. Detailed procedure is worked out, and applied to the data for the H_2O–NH_3 system for all compositions and for vapor-pressures up to 10,000 mm. Hg. The method is fundamentally sound, because it yields correct values for the heat of vaporization of H_2O from known values for the heat of vaporization of NH_3, and because it permits correct evaluation of the *vapor-pressures* of *saturated* solutions from data on unsaturated solutions and the melting-point curve. A calculation of the heat of formation of vapor from solution is given also, for all concentrations, at 25°C.

(699) The origin of the Mid-Atlantic Ridge. Henry S. Washington. J. Maryland Acad. Sci. 1, 20–29. 1930.

The "Mid-Atlantic Ridge" is a submarine mountain range that extends down the middle of the Atlantic Ocean, from about Lat. 50° N. to 40° S., a length of nearly 9000 miles, running parallel with the coasts to the east and west. On it lie several volcanic islands and the islets of St. Paul's Rocks, near the equator (see No. 702). The Ridge is one of the most striking features of the ocean floors and its origin has been much disputed.

It has been considered by some to be an anticlinal rise along the middle of the great Atlantic geosyncline, the consequence of initial crumpling produced by pressure. By others it is regarded as a remnant of the original surface left when the original continent split in two, and the parts drifted asunder, according to Wegener's hypothesis of continental drift. The peridotite of St. Paul's Rocks (see No. 702) is held to be decisive as to the origin of the Ridge, because of its schistose texture, which has been produced by pressure. The Ridge is, therefore, held to be of anticlinal origin, caused by compression of the ocean floor, and as not favoring Wegener's hypothesis. Prinz' hypothesis of differential torsion of the northern and southern hemispheres is suggested as offering an explanation of the shape of the Ridge.

(700) **Mount Katmai and Mount Mageik.** Clarence N. Fenner. Z. Vulkanol. 13, 1-24. 1930.

In this article an account is given of ascents of these two volcanic peaks in the Katmai region, Alaska, with the results of a study of their previously unexplored craters. The various volcanic phenomena of the craters are described, as well as the geologic structure of the mountains. The study is then extended to a consideration of the structure of the Aleutian Range and adjacent areas, both in the Katmai region itself and in regions to the northeast and southwest. It is shown that the sedimentary strata of all this territory, both in places where they are partly veneered with lava flows, and where they are more plainly exposed, are prevailingly horizontal or gently inclined, that steep dips are rather rare, and that sharp plications are almost absent.

This structure of the Alaska Peninsula does not seem to accord well with theories which some geologists have expressed in regard to the method of formation of this festoon on the northern border of the Pacific Ocean. There is little evidence of a dominance of tangential thrusting in the Alaska Peninsula, but instead vertical movements seem to have prevailed.

(702) The petrology of St. Paul's Rocks (Atlantic). Henry S. Washington. (Chapter 12, pp. 126-144, from report on *Quest* expedition. British Museum, 1930.)

Specimens collected by the *Quest* expedition were studied. The small islet group, situated in the middle of the Atlantic, is made up of a peridotite, specifically a wehlitic dunite, composed almost wholly of olivine, with a little pyroxene and spinel. A chemical analysis was made and it is compared with other such peridotites. The rock is very remarkable and unique among those of oceanic islands in its composition and because it shows evidence of pressure metamorphism. The origin of the dunite, and especially of its schistose texture, is discussed, and it is suggested that the group is a portion of the Mid-Atlantic Ridge that was raised to the surface by lateral pressure (see No. 699).

(703) The significance of the word "eutectic." Clarence N. Fenner. J. Geol. 38, 159-165. 1930.

Attention is called to the varying ways in which "eutectic" has been used by different writers, and to the confusion that has thereby resulted. With some writers the word is restricted to its original significance of a unique point on a phase rule diagram, and conclusions have been drawn as to the presence or absence of eutectic relations in igneous magmas, while other writers, having in mind a more extended meaning, have been disposed to question the validity of these conclusions.

In other instances eutectic phenomena obtained in the laboratory with dry melts have been compared with results shown in the crystallization of natural magmas, apparently without full realization that in magmas certain factors so change the conditions as to make the conclusions of doubtful application. It is urged that writers should bear these points in mind and should use the word in such a manner as to leave no doubt as to what significance is attached to it.

(704) Rhamnonic lactone, 1,4 and 1,5. Crystallographical and optical properties. F. E. Wright. J. Am. Chem. Soc. 52, 1276–1281. 1930.

Crystallographical and optical measurements made on crystals of 1, 4- and 1, 5-lactones of rhamnonic acid, prepared by Dr. E. L. Jackson and Dr. C. S. Hudson prove that the *l*-rhamnonic lactone of Will and Peters was the 1, 5- rather than the 1, 4-lactone. Rhamnonic lactone 1, 5 crystallizes in the orthorhombic crystal system, class bisphenoidal; crystals are in the form of short, stocky prisms 1 to 3 mm. long; axial ratio a:b:c = 0.6874:1: 1.2592; refractive indices for sodium light, $\alpha = 1.514$, $\beta = 1.546$, $\gamma = 1.592$; optical orientation, $a = \gamma$, $b = \alpha$, $c = \beta$; optic axial angle, $2V\gamma = 82°10'$; dispersion of optic axes, slight; optical character, positive. Rhamnonic lactone 1, 4 crystallizes in the orthorhombic crystal system, holohedral division; crystals are prismatic in shape, but not so clear and well developed as the 1, 5-lactone crystals; axial ratio a:b:c = 0.7772:1:0.3484; refractive indices, for sodium light, $\alpha = 1.497$, $\beta = 1.525$, $\gamma = 1.532$; optical orientation $a = \gamma$, $b = \beta$, $c = \alpha$; optic axial angle, relatively small, $2E\alpha = 80°44'$ for red light (0.65μ) and $2E\alpha = 76°30'$ for blue light (0.48μ); dispersion of optic axes, noticeable; optical character negative.

Will and Peters were the first to prepare and describe rhamnonic lactone in 1889; their preparations, however, contained both the 1, 4- and the 1, 5-lactones. The chemical properties of the 1, 4 form were measured; but the optical and crystallographical measurements were made on the 1, 5 form. For forty years the data of Will and Peters were considered to characterize the one form of rhamnonic lactone known. In the present paper the chemical evidence of Doctors Jackson and Hudson, pointing to the existence of two forms of rhamnonic lactone, is substantiated by both crystallographical and optical measurements.

(705) The cristobalite liquidus in the alkali oxide-silica systems and the heat of fusion of cristobalite. F. C. Kracek. J. Am. Chem. Soc. 52, 1436–1442. 1930.

The cristobalite liquidus in alkali silicate systems shows a progressive change of contour, being approximately ideal in the cases of Rb and Cs, and having a pronounced reverse S curvature in the cases of Na and Li. The periodic progression is regular and continues in the alkaline earth silicate systems. The liquidus curves were determined for all the alkali systems, and 30.5 cal/g was calculated for the heat of fusion of cristobalite from the limiting slope of the curves obtained with Rb and Cs.

(706) Calorimetry in furnaces. Walter P. White. J. Phys. Chem. 34, 1121–1136. 1930.

Specific heats, up to temperatures from 200° to 1500°, have usually been determined by dropping the substances investigated from the hot furnace into a calorimeter. Most of the measurements are thus made under the favorable conditions provided by room temperature, and the furnace can be carefully brought to equilibrium, at stationary temperature, before the measurement in it. Latent heats have also been determined by this method, but more often, perhaps, by heating or cooling within the heating or cooling furnace, with the experimental material itself playing the rôle of calorimeter. There is some desire to use such methods for specific heats also, in order to gain speed, and for other reasons. Their precision hitherto, compared to that of the dropping method, has been decidedly inferior.

The experiments described were undertaken to find the value of various schemes for increasing this precision, in both latent heat and specific heat determination. The following conclusions were reached: Electric heating of the calorimeter within the furnace can easily be made adequate in amount, though the uniform distribution of this heat still remains a problem. Very small dimensions, diameters of a centimeter or two, are best for furnace calorimeters, though with them the probable error from thermal leakage in a given time is over a thousand times that with an ordinary calorimeter. The temperature should nearly always be measured at the outer wall of the little calorimeter. For specific heat determination, comparison or substitution methods, working from material whose specific heat is known, seem almost the only hope, and their precision will seldom be a tenth as good as that of the dropping method, unless some superior technique can be invented. Latent heat determinations with the aid of electric heating promise much better, since the time, and therefore the thermal leaking, can be made relatively small, and the furnace temperature is nearly stationary, and can therefore be better controlled and known. Even so, the dropping method is superior, wherever conditions are reasonably favorable for it.

(707) **Curtisite, a new organic mineral from Skaggs Springs, Sonoma County, California.** F. E. Wright and E. T. Allen. Am. Mineral. 15, 169-173. 1930.

This mineral occurs in small aggregates of crystal flakes scattered through the porous sandstone of the Franciscan formation in association with opaline silica, realgar and metacinnabarite. Its color is yellow to pistachio green; luster, vitreous to adamantine. Hardness, less than 2; specific gravity, 1.235 to 1.237. Fracture conchoidal; cleavage, perfect after the basal pinacoid, poor after the front pinacoid. Crystal system, probably orthorhombic. Refractive indices, $\alpha = 1.557$, $\beta = 1.734$, $\gamma = 2.07$. Optic axial angle, large, $2V\gamma = 83.5°$; optical character positive; dispersion of optic axes slight, $2V_r > 2V_v$. The acute bisectrix emerges apparently normal to the cleavage plane 001; the plane of the optic axes is normal to 100.

The mineral is slightly soluble in hot acetone, amyl acetate, butyl alcohol, petroleum ether; less than one-half per cent is dissolved in hot carbon bisulfide, carbon tetrachloride, chloroform, ether; one-half per cent, in boiling benzol; 2.5 per cent, in hot xylol; over 10 per cent, in hot aniline. From combustion analyses made by Dr. F. B. La Forge and by F. E. Wright, and from molecular weight determinations made by Dr. M. Phillips and by F. E. Wright, it is probable that the correct chemical formula for curtisite is $C_{24}H_{18}$. The recrystallized, purified compound melts at 370°C., at the same time turning black. Heated over an open gas flame in a small glass tube, the mineral melts readily to a clear liquid that discolors rapidly. Heated in a tube open at both ends, the mineral sublimes readily and is deposited on the cooler walls of the tube in very thin flakes.

(708) The use of the grid glow tube in a thermoregulator. James H. Hibben. Rev. Sci. Instr. 1, 285-288. 1930.

The use of the grid glow tube, as an alternative to the three electrode valve in electrical circuits requiring a sensitive control device, is described.

Schematic diagrams are given showing the application of the tube in the Wheatstone bridge and photo-electric cell methods of temperature control. Its advantages over the triode are discussed and the most favorable operating conditions are indicated.

(709) **Experimental procedure and the kinetics of the N_2O_5 decomposition at low pressures. James H. Hibben. J. Phys. Chem. 34, 1387–1398. 1930.**

The various hypotheses concerning the kinetics of chemical change in gaseous systems are discussed. The contradictory experimental results obtained by different workers are attributed to inadequate experimental technique. The experimental procedure employed by Rideal, Tolman, Sprenger, Schumacher and others in investigating the kinetics of the nitrogen pentoxide decomposition at low pressures is critically reviewed in detail and possible sources of error indicated.

The conclusion of Loomis and Smith that condensation of a solid in the presence of oxygen at low pressures leads to its appreciable adsorption and occlusion is found to be invalid. The amounts experimentally determined are as follows: With N_2O as the condensate no adsorption occurs; with N_2O_5 the decrease in oxygen pressure is 0.0009 mm. Hg; with NO_2 the decrease amounts to 0.0001 mm. Hg, the initial oxygen pressure being slightly greater than 0.01 mm. Hg in each case.

It is shown that the practice of collecting oxygen by means of a Toepler pump for quantitative determinations may introduce serious error, inasmuch as 27 per cent of the oxygen at 0.02 mm. Hg pressure is removed by 30 c.c. of mercury.

A new type of thermal conductivity gage for low pressure measurements is described.

(710) The system sodium oxide-silica. F. C. Kracek. J. Phys. Chem 34, 1583–1598. 1930.

The system Na_2O–SiO_2 contains three binary compounds, the orthosilicate ($2Na_2O.SiO_2$), the metasilicate ($Na_2O.SiO_2$) and the disilicate ($Na_2O.2SiO_2$). The orthosilicate decomposes at 1120° ± 5° (in mixtures containing less than 40.7 per cent SiO_2) before its melting point is reached. A new value, 1089° ± 0.5°, is given for the melting point of the metasilicate, and Morey and Bowen's value for the melting point of the disilicate, 874° ± 1°, is confirmed. The ortho-metasilicate eutectic is at 43.1 per cent SiO_2 and 1022°, and the meta-disilicate eutectic is at 62.1 per cent SiO_2 and 846°. The stable eutectic between the disilicate and quartz is located at 73.9 per cent SiO_2 and 793°, and the metastable one between the disilicate and tridymite at 74.6 per cent SiO_2 and 782°. Sodium disilicate has a reversible inversion at 678°. At temperatures above 706° it takes up excess Na_2O, above 768° excess SiO_2 into solid solution. The problems connected with the investigation of the orthosilicate region are discussed in detail.

(711) **The compressibility of rubber. L. H. Adams and R. E. Gibson. J. Wash. Acad. Sci. 20, 213–223. 1930.**

Direct measurements were made of the fractional change in volume undergone by samples of rubber when subjected to pressures up to 12,000 bars. The samples investigated were: hard rubber, containing 27 per cent of sulphur and two specimens of soft rubber, containing 10 and 5 per cent of sulphur respectively. Between 1 and 12,000 b. the changes in volume for the specimens in descending order of sulphur content are 13.3, 16.1 and 18.5 per cent of the volume at 1 b. respectively. The compressibilities of the samples arranged in like order fall from 19.2, 35.2 and 36.6 at 1 b. to 6.3, 5.9 and 6.3 at 12,000 b. The compressibilities are fractional volume-changes expressed in parts per million per bar. The course of the compressibility-pressure curve of soft rubber is strongly suggestive of that of a liquid.

(712) The polymorphism of sodium sulfate. IV: X-ray analysis. F. C. Kracek and C. J. Ksanda. J. Phys. Chem. 34, 1741–1744. 1930.

Three forms of Na_2SO_4 have been detected by the X-ray method. These are Na_2SO_4I, stable above 240°, Na_2SO_4V or thenardite, stable at ordinary temperatures, and Na_2SO_4III, metastable below 185°, but inert, when dry, at ordinary temperatures. A pattern of $Na_2SO_4.10H_2O$ was also taken for reference.

(713) The Engels copper deposits, California. Clarence N. Fenner. Econ. Geol. 25, 420–425. 1930. (Discussion of article by Adolph Knopf and C. A. Anderson.)

The original article by Knopf and Anderson contained a description of an ore body believed by the authors to represent a deposit formed under pneumatolytic conditions. In the discussion this view is favorably commented upon, and the description of the characteristics of the deposit is compared with what we should expect. The conditions under which mineral matter is volatilized are touched upon. A generalized picture is presented of the manner in which magmatic segregation, gaseous transfer, and hydrothermal solution may all play a part in the formation of ore bodies around an igneous intrusion.

(714) Central African volcanoes in 1929. N. L. Bowen. Trans. Am. Geophys. Union, 10th and 11th Annual Meetings, pp. 301-307. Nat. Res. Council, Washington, D. C. 1930.

The volcanic region near Lake Kivu was visited in 1929 by Professor Bailey Willis and N. L. Bowen. The two volcanoes Ninagongo and Namlagira were in an active state at the time of the visit. Namlagira was ascended and the crater with its playing lava fountains and solfataras was observed at close range.

(715) Analytical methods in phase rule problems. George W. Morey. J. Phys. Chem. 34, 1745–1750. 1930.

A discussion of a mathematical method for treating systems containing numerous constituents, with particular application to the analytical equations for the n-fold, (n-1)-fold, etc. in a system of n + 1 components.

(716) Annual Report for this year.

(717) The ternary system K_2O–CaO–SiO_2. G. W. Morey, F. C. Kracek and N. L. Bowen. J. Soc. Glass Technology 14, 149–187. 1930.

The various rock-forming oxides are in the main non-volatile under ordinary melting conditions for the temperature range from 1000° to 1500°C. This, however, is not true of the oxides of sodium and potassium, and they are of great importance as essential ingredients of many rock-forming minerals, among which we may mention only the ubiquitous feldspars. Systems containing either of these oxides are in general more difficult to study because their volatile character introduces experimental difficulties, in composition ranges high in the alkali oxides, in both cases regions of very high temperature; and also because of the slow attainment of equilibrium in the composition regions which lie near the most siliceous eutectics, in both cases found at characteristically low temperatures. These low-temperature eutectics play an important part both in the crystallization of igneous rocks and in the artificial production of siliceous industrial materials, particularly glasses. This fact was brought out in a previous study of the ternary system $Na_2O.SiO_2$–$CaO.SiO_2$–SiO_2, but the characteristics which make it true are still more marked in the ternary system K_2O–CaO–SiO_2, the major portion of which is covered by the present study. This system differs notably from the previously discussed system containing Na_2O, especially in the following particulars: in the formation of a larger number of compounds; in the greater tendency of these compounds to dissociate on melting; in the greater viscosity of the potash-bearing liquids at the melting temperatures, especially near the boundaries of the silica fields; and in the greater sluggishness of crystallization and melting of the K_2O mixtures.

The following new compounds were found in the system: $K_2O.CaO.SiO_2$, with a congruent melting point at 1630°; $2K_2O.CaO.3SiO_2$, with an incongruent melting point at 1005° at which it breaks up into $K_2O.CaO.SiO_2$ and liquid; $K_2O.3CaO.6SiO_2$, analogous to a corresponding compound in the Na_2O system, with an incongruent melting point at 960° at which are formed liquid and $K_2O.2CaO.6SiO_2$; a series of disilicate compounds, $4K_2O.CaO.10SiO_2$, $2K_2O.CaO.6SiO_2$, and $K_2O.2CaO.6SiO_2$, of which the first two have congruent melting points at 946° and 959° respectively, and the third has an incongruent melting point at 1115° where it breaks up into wollastonite and liquid; and the compound $K_2O.2CaO.9SiO_2$ (a trisilicate of a general composition different from any other known compound) with an incongruent melting point at 1050°, forming $K_2O.2CaO.6SiO_2$ and liberating SiO_2. The lowest temperatures found in the system are those of the two eutectics at which $K_2O.4SiO_2$ and $K_2O.2CaO.9SiO_2$ coexist in contact with liquid and either SiO_2 or $K_2O.2SiO_2$, both of which eutectics are at 720°.

(718) Isotopes and the problem of geologic time. Charles Snowden Piggot. J. Am. Chem. Soc. 52, 3161–3164. 1930.

A paper, in sequence with Laboratory Paper No. 659, of the nature of a report read before the spring meeting of the American Chemical Society; pointing out that of the three phenomena so far used for the determination of geologic time: (1) denudation and sedimentation, (2) the salting of the Ocean, (3) radioactive disintegration of uranium into lead, only the last can be measured with the accuracy necessary to inspire confidence in the result.

It describes the determination of the isotopes of "ordinary" and later of "radioactive" lead and gives the data and reasoning for fixing the origin of the actinium series and the atomic masses of its members (both hitherto unknown). Work leading toward the determination of the isotopes of uranium is mentioned and the great need and value of this information is stressed.

(719) The ternary system: Na_2SiO_3–Fe_2O_3–SiO_2. N. L. Bowen, J. F. Schairer and H. W. V. Willems. Am. J. Sci. 20, 405–455. 1930.

In this paper a study of crystallization equilibrium in the system: $Na_2O.SiO_2$–Fe_2O_3–SiO_2 is presented. The study was carried out by the method of quenching and the results are given in five tables and discussed with the aid of fourteen figures.

The equilibrium diagrams show the existence of two ternary compounds, whose compositions lie within the triangle; the one familiar as a rock-forming mineral, acmite ($Na_2O.Fe_2O_3.4SiO_2$); the other a new compound, $5Na_2O.Fe_2O_3.8SiO_2$, of hexagonal crystallization. In addition there is a third ternary compound, $6Na_2O.4Fe_2O_3.5SiO_2$, whose composition lies outside the triangle (at a more sodic composition) but whose field extends into the triangle. The compound, $5Na_2O.Fe_2O_3.8SiO_2$, melts congruently at 838°C. The compound, $Na_2O.Fe_2O_3.4SiO_2$ (acmite) melts incongruently, with separation of hematite, at 990°C.

As a consequence of the extension of the hematite field beyond the composition of acmite (incongruent melting) there result some very interesting crystallization courses in mixtures rich in acmite. In some mixtures, for example, hematite crystallizes out at an early stage, is completely resorbed by reaction with the liquid at intermediate stages and again crystallizes out at late stages. This reaction relation of hematite introduces, under conditions of fractional crystallization, some markedly different alternative courses of crystallization with one and the same original liquid. These are discussed with the aid of a crystallization diagram which shows that, with strong fractionation, the final liquid attains the lowermost eutectic, at which acmite, sodium disilicate and quartz are formed.

A discussion is given of the application of the results to petrology. Attention is directed to the fact that in this system, as in all systems yet investigated in which SiO_2 is one of the components, the lowest eutectic is at a high silica percentage and this eutectic is the goal reached in the crystallization of a wide range of liquids, especially when fractional crystallization occurs. From this eutectic mixture, and from adjacent mixtures, quartz crystallizes without the intervention of any volatile components, which components have so often been assumed to be essential to the crystallization of quartz. The production of alternative residual liquids by fractional crystallization is applied to similar phenomena in natural magmas and it is shown that the production of an iron-rich residual liquid during the crystallization of basaltic magma under certain conditions is no bar to the production of a siliceous-alkalic residual (granite or syenite) under other conditions.

(720) The devitrification of soda-lime-silica glasses. George W. Morey. J. Am. Ceram. Soc. 13, 683–713. 1930.

In 1925, Morey and Bowen published a study of the liquidus relations in the ternary system $Na_2O.SiO_2$–$CaO.SiO_2$–SiO_2, a portion of which is of fundamental importance to the glass industry. That study has aroused great interest among glass technologists, as shown by the appearance of numerous papers dealing with the devitrification of commercial glasses. This paper gives a more detailed study of the composition field of importance to glass technology, namely, the field of the compound $Na_2O.3CaO.6SiO_2$ and the adjoining portions of the neighboring fields, and enables the liquidus temperature of any soda-lime glass to be determined within a few degrees by interpolation. An extended discussion is given of the process of devitrification, in which is emphasized the importance of knowledge of the liquidus relations; and it is pointed out that surface tension can not have the importance in determining crystallization that is often ascribed to it, and that viscosity is the dominating factor.

(721) The effect of magnesia on the devitrification of a soda-lime glass. George W. Morey. J. Am. Ceram. Soc. 13, 714–717. 1930.

The effect of magnesia on the devitrification of a soda-lime glass of approximately the composition $Na_2O.CaO.6SiO_2$ has been studied by replacing CaO by MgO, and by adding MgO to the parent glass. Replacing CaO by MgO has but little effect on the melting point, and the glass remains in the tridymite field, while on addition of MgO the melting point is lowered, and the glass quickly passes into the field of $Na_2O.3CaO.6SiO_2$. These experiments indicate that addition of MgO would have a beneficial effect on a soda-lime glass, while replacing CaO by MgO would be of doubtful value; but it is emphasized that these experiments represent but two excursions into the quaternary system $Na_2O–CaO–MgO–SiO_2$, both starting from the same point, and in arbitrary directions, and complete knowledge can only be gained by a study of the entire quaternary system.

(722) **The effect of alumina on the devitrification of a soda-lime glass.** George W. Morey. J. Am. Ceram. Soc. 13, 718–724. 1930.

The effect of alumina on the devitrification of a soda-lime glass of approximately the composition $Na_2O.CaO.6SiO_2$ has been studied by replacing CaO by Al_2O_3, and by the addition of Al_2O_3 to the parent glass. Replacing CaO by Al_2O_3 results in a sharp lowering of the melting point, and the glass passes from the field of tridymite into the field of $Na_2O.3CaO.6SiO_2$ with about 2 per cent alumina. It is to be inferred from this that the boundary surface separating the tridymite field from that of $Na_2O.3CaO.6SiO_2$ in the tetrahedron representing the quaternary system is convex toward the SiO_2 apex. On further replacing CaO by Al_2O_3, the glass passes into the wollastonite field, and finally into the field of the mineral albite. Glasses containing a large proportion of this latter compound are exceedingly difficult to crystallize in the dry way, yet are readily crystallized by hydrothermal methods. When Al_2O_3 is added to the parent glass, the lowering of melting point is neither so sharp nor so great, but the melt quickly passes into the field of $Na_2O.3CaO.6SiO_2$, then into the field of wollastonite. It is to be expected that a small content of alumina will be beneficial to any soda-lime glass; but complete knowledge of its effect requires the study of the quaternary system $Na_2O–CaO–Al_2O_3–SiO_2$ in all its details, a study which also would be of importance in its applications to geological problems

DIVISION OF HISTORICAL RESEARCH[1]

A. V. KIDDER, CHAIRMAN

This Division, which was created by act of the Board of Trustees of the Institution in December 1929, comprises a Section of Early American History, a Section of Modern American History and a Section of the History of Science. Working in collaboration with one or other of the Sections are certain investigators from other institutions. The Division has both administrative and coordinative functions. As an administrative unit it serves those groups within the Instituton which are engaged in the study of man's history, in the broadest sense of that word. In its less formal capacity it is designed to promote intercourse between the Institution's workers in the humanistic field; to direct attention to and integrate research upon problems which are of fundamental importance for all students of man's career, but which are too complex and too ramified for successful attack by any single specialized discipline; and, finally, it aims to facilitate cooperation between the Sections and other scientific agencies.

The present report is devoted largely to the work of the Section of Early American History because the problems of that group have been such as to require particularly careful consideration during the past year. They also well exemplify the type of coordinated research which the Division hopes to sponsor.

SECTION OF EARLY AMERICAN HISTORY

In designating the group engaged in studies of the pre-Columbian career of the American Indians, the term history has been used as symbolic of a desire to do away with the somewhat rigid distinction which has generally been drawn between archeology and history. The work of the Section is, of course, archeological in that it deals with material remains rather than with written records. But archeologists seek to gather from ruined buildings and potsherds the same sort of knowledge that historians derive from books and manuscripts, and while the subject matter and, therefore, the primary methods of the two disciplines are naturally unlike, their ultimate aims are identical, for both archeology and history strive to recover and to interpret the story of man's past. Archeology, however, has all too generally been prosecuted as if the excavation of specimens were an end in itself. Antiquities have, as a rule, been collected more for their rarity or their beauty than for what they might tell of the doings and the thoughts of the human beings who made them. Emphasis in archeology is gradually shifting, however, from things to what things mean; and archeological finds are fortunately coming more and more to be considered as historical documents.

In its work in the Maya field of Middle America and in Southwestern United States, the Section is exceptionally well placed to aid in further development of the modern conception of archeological research. The Maya represent perhaps the highest peak of native American civilization; the ancient Southwesterners were laying the foundations of communal agricultural existence. Each people, therefore, illustrates a most significant stage in human progress. And their remains cover such long periods of time and embrace such remarkable growths of culture that they force upon the student a keen realization of the deep perspectives of history. Finally, the problems raised by excavation, both in the Maya country and in the Southwest, are so obviously insoluble without help from many other branches of science, that the archeologist is impressed by the very necessary truth that his work is merely one small part of the single great investigation of man's evolution.

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MAYA STUDIES

The Maya, as has been intimated, were the most brilliant people of the aboriginal New World. Their civilization had its roots in the primitive farming culture, which originated well before the birth of Christ, somewhere in the Middle American highlands or in the Andean region, and which through ramification and diffusion ultimately gave birth to all the higher pre-Columbian developments in the Western Hemisphere. The Maya, whose earliest known remains lie in the forested plains at the base of the Yucatan peninsula, took over or brought with them from the highlands the elements of this primitive culture: corn-growing, pottery-making and presumably also the rudiments of their later artistic, religious and social systems. In the low country they flourished like a tropical flower. Their glyph-recorded history begins at about the time of Christ (according to Dr. Morley's correlation of Maya and Christian chronology), but before then they must already have spent many centuries in perfecting the material arts, and particularly the extraordinary astronomic and calendrical knowledge of which we find them possessed even at that remote period The great epoch of Maya history, the Old Empire, saw the building of Tikal, Copan and many other magnificent and temple-adorned cities. The causes for the eventual break-up of the Old Empire are as yet unknown, but decay it did, and the formerly populous southern region reverted to jungle. The Maya, however, had already been pushing northward into Yucatan, and there, during the New Empire at such cities as Chichen Itzá and Uxmal, they enjoyed a remarkable renaissance. Ultimately they fell under dominance of the rising Nahuatl powers of Central Mexico and, at the time of the Conquest, were once more undergoing a period of decadence. What would have happened if the Spanish had not come; whether they would again have rallied and pushed on to still further heights; or whether they, like the ancient Greeks, whom in many ways they so closely resembled, had finally expended all vital and creative energy, are questions of more than merely academic interest, for the Maya still form the bulk of the population of Yucatan and of Guatemala, and the future of those countries therefore depends to a large degree upon the ability of these Indians to receive European culture, to adapt it to their needs and to develop it in such a way as to permit them to play a worthy rôle in the modern world.

Even so brief a resumé indicates the importance of research upon the Maya. To the New World historian it is naturally of paramount significance, for the Maya were leaders in the cultural development of Middle America, influencing directly or indirectly all other groups in that entire area. The Maya, too, were the only people who consistently and accurately recorded dates, thus providing a starting point from which to work out the chronology of all the other high pre-Columbian cultures. For the student of more general problems, the Maya also provide invaluable data. Their history involves the rise, spread, efflorescence and decline of an agricultural civilization. It gives splendid opportunities for evaluating the influence of those racial and environmental factors which have been so potent in shaping the destinies of all peoples, but whose action has been so little understood.

Carnegie Institution entered the Maya field in 1914 when Dr. S. G. Morley was appointed Research Associate. The activities of Dr. Morley and his staff fall into sequent periods of exploration and excavation.

The soundest method for attacking any archeological problem is to conduct a preliminary survey of the area concerned in order to determine the general distribution of its remains, to sense the broader aspects of historical trends, to identify the lines of evidence which will best repay close study, and finally to select for intensive excavation the key sites which will yield the fullest information upon the customs and the career of the people who are being studied. Pursuing the above principles, Dr. Morley devoted approximately ten years to exploring the Maya area from end to end. He visited practically all previously known sites and discovered many new ones, the most important being Uaxactun, Xultun and Naachtun. Accounts of his very difficult journeys may be found in the Year Books of the Institution. Their result was a much more definite knowledge than had hitherto existed of the territory occupied by the Maya at different periods of their career; and an evaluation, based on the abundance and quality of remains, of the significance of each of those periods. In other words, a definite historical outline was achieved. Dates, hieroglyphically inscribed, formed the primary evidence for Dr. Morley's determinations. At the same time by deciphering cryptic inscriptions and by finding and reading many new ones, he much more than doubled the known number of these invaluable glyphic time-markers.

For intensive excavation were selected Chichen Itzá in northern Yucatan, Mexico, and Uaxactun in the Department of the Peten, Guatemala; reconnaissance digging was also to be done at Tayasal on Lake Peten Itzá. These three sites cover the entire range of Maya history: Uaxactun is, on the basis of recorded dates, the oldest Maya city; Chichen Itzá was founded before the abandonment of Uaxactun and was occupied until shortly before the coming of the Spaniards; Tayasal, the last independent stronghold of the Maya, did not fall until the close of the seventeenth century.

THE UAXACTUN PROJECT

From the time of its discovery in 1916, Dr. Morley felt that Uaxactun merited thorough investigation. It was not only the oldest Maya city known, but its inscriptions indicated that it had been inhabited for upwards of five and a half centuries. It gave promise, therefore, of throwing light on the whole period of the Old Empire, and he believed it possible that it might even yield data upon the formative stages of Maya culture.

Uaxactun was surveyed and mapped for the Institution by Mr. Frans Blom in 1923. In 1925 a contract was entered into with the Government of Guatemala for a five-year project, with privilege of renewal; and in the same year the Institution's work there began under direction of Mr. Ricketson. Five field-seasons have now been devoted to excavations. They have centered about one of the large temple-surrounded plazas of the city, attention having originally been directed to this particular quarter by the fact that certain of its monuments and buildings gave evidence of being so placed as to produce lines of sight of astronomical significance. The question as to whether or not Plaza E was in reality an observatory involves complex and still unsolved problems of Maya astronomy and the Maya calendrical system. But the excavations of Mr. Ricketson, undertaken to establish the exact orientation of building units thought to be involved in the observatory complex, have produced purely archeological data of the greatest interest and importance. The western side of the plaza was fronted by a large pyramid, worn by time and the inroads of the jungle to a peaked mass of crumbling stone. Work on its eastern face, in an attempt to locate remains of a stairway, disclosed underneath the débris a grotesquely modeled mask of heroic proportions, which further digging showed to be part of the adornment of an earlier structure, entirely covered by and embalmed in perfect preservation within the later pyramid. To bring it fully to light required part of the season of 1927 and the entire season of 1928, when it stood revealed as a beautifully proportioned truncated pyramid, its flat top approached by four stairways flanked by series of great masks. Its terminal platform bore no temple, and it therefore seems likely that it served in itself as a huge altar, or elevated place for holding important ceremonies.

The construction is lime stucco over a core of crude masonry. Had it not been sealed in and protected from the elements, the plaster shell, including the stairways and masks, would quickly have disintegrated. Such has, indeed, apparently been the fate of all unprotected early Maya buildings. This example, therefore, stands as our only illustration of the architecture of its period. It differs strongly from anything heretofore known, but it exhibits an astonishing sophistication of line and mass, a feeling for the subtleties of contour and the play of light and shade, which can only be interpreted as the result of long practise in the designing and erection of this type of structure. It is certainly very old. Its exact age still remains to be determined, and for this purpose Mr. Ricketson is making studies of the levels of the plaza fronting it and of their relation to dated stelæ.

As soon as the pyramid was cleared it was realized that most careful record must be made of its appearance, for it could not be expected long to withstand the ravages of a tropical climate and the inevitable encroachments of the jungle. It was photographed in the large and in all detail, planned and sectioned in every aspect. The mapping was a most difficult task, for the thing was, so to speak, a gigantic piece of sculpture, no two of its lines being parallel, no two angles the same. But from the data brought back it has been possible during the present year for Mr. S. J. Guernsey tq prepare an accurate model which will be shown for the first time at the annual exhibit of the Institution in December 1930.

When the buried pyramid had been uncovered, pits were sunk in front of it which showed that, old as it doubtless is, there exist below it and also under the plaza to the east deposits of even greater antiquity, consisting of layers of refuse, presumably village débris, which contain abundant fragments of pottery and figurines distinctly un-Maya, as that term is generally understood, but obviously resembling the so-called "archaic" remains of the Guatemala highlands. This was a discovery of the very greatest value. Up to 1928, when the find was made, no definite evidence was in our possession for connecting the Maya civilization with the early cultures from which it was theoretically supposed to have sprung. But here, lying directly below the most ancient known specimen of Maya architecture, itself presumably dating from the very first part of the Old Empire, were materials in undoubted stratigraphic position because sealed in by subsequent constructions, which will make it possible to judge the quality of the transition between the ancestral plateau culture and that of the nascent Maya.

Because of the great importance of the remains beneath the plaza, the seasons of 1929 and 1930 were devoted to a painstaking dissection of the underlying strata. It proved to be a heart-breakingly complex undertaking as the whole place was leaved and interleaved with floor levels and living surfaces, each one of which had to be followed to its ultimate termination over or under or against some unit of construction or some significant bed of débris. Much was learned as to the habits of the Maya city planners in the laying out of their temple-surrounded courts. The large collections of pottery, clay figurines and other artifacts from the different levels have now been moved to Guatemala City, where they are under study by Mr. and Mrs. Ricketson and Mr. Smith.

While the plaza excavations were going on, Mr. Smith carried out a series of detailed studies on the relation between dated monuments and plaza floors in an attempt to determine their chronological relation to the buildings near them. As result, he believes that stelæ were at least occasionally moved from the position of their original erection. The investigation ties in very closely with that of Dr. Morley on the growth and meaning of Maya ceremonial centers. Another research by Mr. Smith concerned itself with the density of population within the city limits, so to speak, of Uaxactun. The work was based upon a careful count of the house-mounds in a surveyed area and estimates of the number of persons per family. Several unknown quantities are naturally involved, such as the likelihood that not all the houses represented by the mounds were occupied at the same time, but his general conclusion is that the immediate vicinity of the temple groups was very thickly populated.

Dr. Morley's selection of Uaxactun for excavation has already amply been justified, but it is a question whether or not work at so inaccessible a site should go forward indefinitely. It lies in the heart of the Peten jungle. Supplies and staff must be transported from the coast up the shallow and winding Belize River in dugout canoes towed by motor launches, a journey of from two days upward, depending on the stage of the water. From the head of navigation at El Cayo, four days on mule-back over very bad trails are required to make the fifty-five miles to Uaxactun. There the water supply is extremely precarious. Added to such difficulties are swarms of insects and a debilitating tropical climate. Hence the cost, both in money and in human effort, of excavating at Uaxactun is necessarily extremely heavy, and while the city still has without question much to yield, it is possible that the work already done has skimmed the cream, as it were, from the site; and it might perhaps in the long run be more efficient to postpone further investigation until such time as the inevitable opening up of the country will render work there more easy of accomplishment.

The check-up of the Uaxactun results now being made by Mr. Ricketson and his staff should go far toward answering the question. Should it be decided to go elsewhere, two obvious follow-ups present themselves. On the one hand, it would be of great value to excavate in the highlands in order to collect archaic material for comparison with the sub-plaza pottery and figurines, thus approaching the problem of origins from the lower end; on the other, one might attempt to trace the Old Empire culture, as made known by the excavations at Uaxactun, northward and eastward into the Peninsula of Yucatan. At all events, work will be continued until the deposits and structures now under investigation have been completed. Decision must also depend upon the development, during the next few years, of the Section's general program, and upon the plans of other agencies in the Maya field.

THE CHICHEN ITZÁ PROJECT

Its outstanding importance in the New Empire and, indeed, until very shortly before the Spanish Conquest, induced Dr. Morley to select Chichen Itzá as the site for the major effort of the Institution's campaign of excavation. The city was founded before the close of the Old Empire, and can therefore be expected to throw light on the earliest developmental phases of the New. During the latter period it was a leader both politically and ceremonially. Better than any other, it illustrates the influence of the Nahua cultures of Mexico upon the Yucatecan Maya. It contains more hieroglyphic inscriptions than any of the late centers. The great length of its occupancy gives opportunity for determination, on the sound basis of stratigraphic observation, of the trends of artistic and material development through many centuries. Its remains are abundant, culturally significant and well preserved. And, finally, it possesses the practical advantages of accessibility, abundant labor supply and healthful climate. Under contract with the Government of Mexico, which from the beginning has been consistently and effectively helpful, excavations were started in 1924 and have continued to date.

The Chichen Itzá project has differed from most archeological undertakings in the New World in that from its inception Dr. Morley has striven for three definite objectives over and above the usual single one of recovering specimens and information. These may be stated as follows: to conduct the work in a manner calculated to create a feeling of confidence by the Mexican government and people in the good faith of foreign scientific agencies; to handle the site in such a way as to make it a permanent record of the artistic achievement of the Maya; and to develop Chichen Itzá as a focal point for correlated researches.

The first of the above mentioned extra-archeological objectives is that of fostering international scientific good will. In some ways this is the most important single aspect of the Institution's work in Middle America; it certainly has been the least understood. To make clear the situation which the Institution is attempting to do its bit to remedy, it is necessary to revert to the statement—made at the beginning of the Section report—that the older archeology considered the acquirement of specimens an end in itself. The retarding effect of this upon the development of archeology as a science need not here be discussed beyond saying that for many years it kept archeology at about the intellectual level of stamp collecting. Its practical results have been almost equally disastrous. For over a century there has been a steady flow of artistic and antiquarian treasures from the countries of their origin to the museums of a few of the larger and richer nations. Much that would otherwise have been lost has of course thus been saved for posterity. But the smaller countries are now coming to appreciate the historic and educational value of such materials, while foreign museums still wish to carry on in the traditional Lord Elgin manner. There has accordingly been a world-wide tightening of laws governing excavation, and in many regions it is now impossible for an outside agency to prosecute any archeological work whatever, while in others it can be done only under conditions regarding disposition of specimens which are so confiscatory that backing for expeditions can not be procured.

The situation as it exists today is very bad and is growing worse. It can only be rectified by concessions on both sides, which in turn must be the result of a new conception of the purpose of archeological work and the meaning of archeological materials. Foreign agencies should realize that the relics of a country's past not only belong rightfully to that country, but that in the long run they are most useful there, always granted that they are adequately protected and are at all times available for study. Foreign agencies should also realize that the primary purpose of their expeditions is study of the history of man rather than the amassing of collections. If these points of view be held they will naturally be content with a fair division of representative material and will not demand all. The home governments, on the other hand, while they are, of course, masters by possession of everything within their borders, should understand that prehistoric man was not bound by modern political limits, that his history is part of a common heritage, and that there is at least an ethical right for all mankind to profit from its study. They should, moreover, take into consideration the fact that, both practically and intellectually, it is to their advantage that their antiquities be known in other lands.

For the purpose of helping to bring about such understandings Carnegie Institution of Washington, in its negotiations with governments and its prosecution of field investigations, has steadily striven to overcome the feeling that the entry of a foreign scientific agency necessarily means wholesale looting of archeological remains. It has frankly stated its adherence to the proposition that title to all antiquities rests in the country of their origin. It has, therefore, exported nothing directly. But it has insisted upon proper care for the materials it has excavated. It has at the same time urged the great desirability of sending representative collections abroad and has recommended gifts by the countries concerned of certain specimens to leading museums. As result, the Mexican government has already placed in the National museums of England, Germany, Peru and the United States series of the beautiful painted stones which emanated from the Temple of the Chac Mool. Although the Institution would not advocate the exportation of unique type material or unduplicable objects of preeminent importance, it hopes that governments of countries in which it works will continue to deposit specimens from its excavations in such outside institutions as can best profit by them.

The attitude of the Institution has rather generally been misunderstood. It has been felt that because it supports no museum it can afford to work without acquiring collections, and that by so doing it has spoiled the field for those who must produce tangible results in objects for museum display. Persons taking this attitude have not realized that it would be infinitely easier for the Institution to remove the product of its excavations to the United States for study and for deposition in places accessible to its workers; or that by direct gifts to museums and by home exhibition of its more spectacular finds it could much more easily than is now the case secure financial backing for its projects. It is probable that, although the policy of the Institution may indeed make things difficult for agencies whose sole desire is to acquire collections, it will in the long run prove distinctly beneficial to those whose primary objective is recovery of historical information and which are willing to share equitably with countries whose ruins they investigate. It seems not unreasonable to believe that the satisfactory relations established between the American Museum of Natural History and the Government of Mexico, both for exploration and the exportation of materials, and the concession recently granted to the University of Pennsylvania by the Government of Guatemala for work at Piedras Negras, have to some degree been facilitated by the manner in which Carnegie Institution has carried on its own researches in those countries.

A second aim of Dr. Morley, in his administration of the Chichen Itzá project, has been so to handle the site as to make it an enduring monument to the genius of the ancient Maya. Chichen Itzá of all great Maya cities is the most accessible and the most healthy. And, with the possible exception of Uxmal, it is without a rival in the number, beauty and architectural distinction of its buildings. What Luxor is to Egypt, or Athens to Greece, Chichen Itzá is to Yucatan. A heavy responsibility, therefore, rests upon him who excavates there.

To derive bare archeological facts would be simple enough. Plazas could be trenched, pyramids torn open and the still standing parts of ruined temples stripped of the mounds which now protect them. These undertakings would be speedy and relatively cheap. But they would pave the way for destruction by weather and vegetation which would very shortly reduce the city to a meaningless jumble of stone. Both the Mexican government and Carnegie Institution have appreciated from the beginning the necessity for care in digging and for leaving all cleared structures in shape to resist further deterioration It has been a costly business, for it has necessitated time-consuming and expensive methods of reaching objectives and has also involved much strengthening and repair of structures in imminent danger of collapse and the replacement of fallen elements which, if left scattered on the ground, would be meaningless and would also be exposed to eventual destruction.

Preservation has not been the only concern. It has been desired that when cleared all buildings should be both understandable and beautiful. Comprehension of an ancient structure demands knowledge of its relation to others, of the methods employed in its erection, of alterations made during its occupancy, and of the factors responsible for the condition in which it was found when excavated. The mere uncovering of an architectural unit will therefore not suffice. Openings must be left to expose earlier remains; sometimes, as in the case of the Temple of the Warriors, large parts of deeply buried pre-existing buildings must be kept intact and rendered accessible. There should be opportunity to examine the interior, even of solid construction, to make plain the methods of the ancient mason. Careful planning permits details of wall and column, vault and roof to be easily seen and studied. And, as at the Caracol, where a section of a great fallen cornice has been held in the exact position of its devastating collapse, there may vividly be illustrated the tremendous forces of destruction.

Intelligent understanding of a building and of what it signifies is made possible by such practical means. But subjective values must not be overlooked. Beauty, in detail and in mass, must be striven for. Unintelligent restoration, no matter how accurate, destroys beauty and so robs ancient structures of their most important psychological effect. The mere fact of ruin induces realization of the inevitable and relentless erosion of time and brings the beholder to the proper frame of mind for grasping the deeper significance of what he sees. Hence repair must not only be meticulously correct but must be limited to essentials and never be blatantly evident.

Different methods are required for each unit undertaken. Archeological knowledge, engineering skill and a keen sense of esthetic values must go to produce the result which it is hoped ultimately to obtain. The cost has been and will continue to be great; but the obligation both in funds and in time is deliberately assumed. In the first place Chichen Itzá, because of its outstanding scientific and artistic importance, deserves our best efforts. Second, it is thought that if the project is handled in a manner so obviously altruistic it can not fail to produce a feeling on the part of the Mexican government and the Mexican people that American agencies can be trusted within their borders. And, third, if Chichen Itzá can be kept both interesting and beautiful, it will without question become a Mecca of travel, and, incidentally, a most valuable asset for archeology which, like every other science, needs its "show-windows." Its more recondite aims the public can not, in the beginning, be expected to grasp; but public interest must be aroused and eventual public understanding must be achieved if archeology is to go forward; for from the public comes, in the last analysis, all support for scientific endeavor.

Adherence to the above policies shaped from the first the course of work at Chichen Itzá and dictated the selection for study of the Temple of the

Warriors and the Caracol, the two principal buildings which have been excavated to date.

The Temple of the Warriors was chosen for first attack because it was the largest example of a type of late structure of which no well-preserved specimen remained, and so might be expected to yield architectural information not to be had from any standing temple in the city. It was also badly, apparently almost hopelessly, ruined, thus giving opportunity to find out what facts could be learned and what materials could be rescued from such a mound, of which literally hundreds exist at Chichen Itzá and other Yucatecan cities. Work at the Temple of the Warriors occupied the four seasons from 1924 to 1928 inclusive. Mr. Morris, who was in charge throughout, has transformed this most unpromising pile of stone into an impressive and lasting monument. Every phase of its long structural history has been elucidated, and every successive increment has been left in such condition as readily to be understandable by the visitor. The finds of sculpture and fresco were abundant beyond all expectation. The final report upon the Warriors by Mr. Morris and his collaborators is now in press.

A second major undertaking has been the excavation and repair of the Caracol, a building of unusual interest in that it is by far the finest and best preserved of the very few round structures in the Maya area, and because there are good grounds for believing it to have served as an astronomical observatory. The Caracol is a great circular tower surmounting a massive rectangular substructure. It possesses many unique architectural features—curved vault, central stem, spiral staircase, and tremendously heavy cornices both on the base and the tower. When work started, the Caracol resembled a jagged tooth of gray stonework protruding from heaped piles of fallen masonry which almost completely masked the contours of the lower part of the tower and of the platform. First attention was devoted to tying into place and so preserving the tottering remains at the top which contained all that was left of the supposed observational passages and their openings. Mr. Ricketson had charge of this greatly needed bit of salvage. The subsequent extensive clearing and rehabilitation have been carried out by Mr. Ruppert. The entire building has been freed of débris, the walls of the tower strengthened and all the great upper cornice replaced, except for a single section which has been left as it originally fell. The platform has proved a mine of information. First one and then a second earlier substructure has come to light, each circular and each enclosed in perfect preservation within later accretions.

Work on the Caracol proper was finished at the end of the present season, but the digging about its base has disclosed a maze of smaller ruins and plaza levels whose relations to it and to adjacent buildings will eventually have to be the subject of careful study. As it now stands, the Caracol, like the Temple of the Warriors, is both understandable and rarely beautiful. Progress reports on the excavations here, at the Temple of the Wall Panels, the Temples of the Lintels, the Temple of the Initial Series, the Temple of the Phalli, and upon the many other smaller undertakings carried on between 1924 and the present may be found in the Year Books.

With completion of the excavation and repair of the Temple of the Warriors and the Caracol, the first phase of the purely archeological work of the Chichen Itzá project has reached a satisfactory conclusion. There must now ensue a period of pause for the digestion and publication of results and the formulation of plans for the future. Digging, as is always the case, has progressed more rapidly than study; and the preparation of reports, which are of course the ultimate and determinative product of all scientific work, has lagged even further behind. The Temple of the Warriors volume is in press, but the Caracol has not yet been described; nor have ten or more smaller excavated buildings, all of much interest and some of great importance, been treated save in summary articles in the Year Book. To get all this material into print and available to the archeological world now becomes the principal task of the Chichen Itzá staff. The papers will be descriptive, but Dr. Morley plans to take advantage of their preparation to begin a thorough study of the details of Maya architecture as manifested at Chichen Itzá.

Information upon the gross aspects of architecture, such as the grouping, orientation, size, ground plan and ornamentation of structures, has been a natural product of the investigation; but close comparative scrutiny of the minutiæ of building practise, the tricks, so to speak, of the mason's trade, has not yet been made; and there is every reason to suppose that intimate knowledge of them will provide an extremely significant criterion for further work.

To make the above statement clear it is necessary to say a word in regard to the handling of specific archeological problems. To begin with, one is dealing with large amounts of undocumented and therefore, at first contact, undatable material which must be ordered chronologically before they can be interpreted in terms of cultural trends or historical events. To make headway with so great a mass, one must select, for preliminary study, certain phenomena or groups of objects which, more clearly or more easily than others, will serve to block out the investigation. These may be called preliminary criteria.

In the Maya field the best and most obvious criterion for determining the relative age of remains is supplied by the hieroglyphs, and Dr. Morley and other students of the Maya were of course prompt to seize upon and exploit this line of research. Their work upon the glyphs, as has already been said, has served to define the main currents of Maya history and to place in their relative order the principal groups of cities. The hieroglyphic record, however, is fragmentary and it has already been rather thoroughly searched. More dates will doubtless be found, but for further advance we must fill in the picture in greater detail; we must not only assign to their proper period the many cities which contain no dates, but we must do the same for individual buildings in the cities, for their chronological ranking will supply us with knowledge of the age and therefore of the meaning of the things they contain.

Success depends upon intelligent selection of the above-mentioned preliminary criteria. The best clues are provided by materials which are abundant and easily acquired, which readily and accurately reflect cultural change, and which are of such a nature that their chronological position may readily be determined. Pottery most ideally fulfills these requirements, and ceramic study is now going forward actively. Pottery, however, is not superficially common in the Maya region, and many years must elapse before enough excavation can be done to supply us with sufficient specimens for valid sequences covering all periods and all parts of the area. Manifestations of the graphic arts, particularly sculpture, are also, as Spinden has demonstrated, a highly useful means of working out chronologies, but much Maya sculpture was in stucco and has either perished or, if preserved, still awaits excavation, and stone stelæ, bas-reliefs and carved ornaments are relatively rare. Our best criterion, at least at the present time, appears therefore to be the details of architecture. The Maya were incredibly diligent builders; the mere act of building would, in fact, appear to have been an integral part of their very coercive religious system. Maya buildings are therefore abundant, and although most of them are in an extreme state of dilapidation, careful study, as has often been proved, will reveal much precise information as to cornices and mouldings, stone-cutting and laying, vault construction, frescos, bas-reliefs, etc., etc. Such features are, by and large, probably the most easily studied manifestations of Maya culture; and, because of the frequent additions that the Maya made to their structures, because of their habit of piling platform on platform and temple on temple, it should not be difficult to determine the chronological relations of much material; and to establish, on the sure basis of stratigraphic evidence, the principal trends of architectural development. Dr. Morley, in his conduct of the excavations at Chichen Itzá, has accordingly laid special stress upon the uncovering of buildings, and Mr. Ruppert and Mr. Pollock are now engaged in careful comparative studies of constructional and ornamental detail. When the architecture and art of Chichen Itzá are intimately known, the work will be extended to other cities of the late period in northern Yucatan, and eventually to the east coast and southward. To aid in the research, Mr. Bolles, a student of architecture with experience in the Gothic and Near Eastern fields, has been added to the staff for the coming year.

The studies of buildings will beyond question prove of great value. But they must be accompanied and supplemented by investigation of other categories of material, of which pottery is by far the most important. The usefulness of pottery as an archeological criterion needs no stressing. It has again and again shown itself to be the single most reliable and most accurate means for establishing the sequence of cultural periods. The prehistory of Egypt, of the Near East, of the American Southwest, of the Valley of Mexico, has been, or is being, outlined on the basis of ceramic evidence. The reason for this, as has often been pointed out, lies in the plasticity of the potters' art and in the fragility of its products, the former quality permitting constant change, the latter insuring both opportunity for modification and abundance of remains in the form of sherds.

Research upon Maya pottery presents many difficulties. To begin with, the mere acquiring of material is a slow and arduous process. Potsherds, so common and so easily collected from the surface in arid regions where the ground surrounding ancient sites is bare, are, in the Maya country, hidden by tangled undergrowth. Even when, after clearing, the earth is laid bare, the fragments are all too often found to be rotted by the corrosive acids of jungle humus. Hence usable specimens must be sought by slow and expensive excavation. Another difficulty is caused by the fact that the Maya had advanced to that stage of development where vessels for everyday use were turned out wholesale and were either undecorated or ornamented conventionally. Fine pieces were, of course, also made, and the evidence provided by these is more easily read; but they are rare, and the run of sherds, the great body of material with which the ceramicist must necessarily deal, can only tell its story after there have been worked out very unobtrusive changes in clay and finish, and very subtle differences in vessel shapes. Lastly, there seem to be several major divisions of Maya ceramics, perhaps of differing origin, certainly more or less independent in development. Some of them are allied to one non-Maya group, some to another, others have no readily perceived affiliations. For their ultimate comprehension there will be required an extremely wide comparative knowledge of Central American pottery from the earliest times onward. So bafflingly complex and yet so urgently necessary a research can not successfully be prosecuted as a side-line of excavation; it demands the best energies of specialists. In this capacity, Mr. H. B. Roberts has joined the staff of the Section.

Ceramic work for the Institution was started in 1926 by Dr. George C. Vaillant, who, on the basis of materials then available from the excavations at Chichen Itzá and of collections in Yucatan and the United States, made a basic classification of the wares of northern Yucatan. He was also able, as result of excavations in the courtyard of the Temple of the Phalli, to suggest a chronological sequence for the majority of the types established by his classification. Continuance of the research was prevented by Dr. Vaillant undertaking, for the American Museum of Natural History, a study of the immensely important archaic remains of the Valley of Mexico, but he has kept intimate touch with the Institution's program; he carried on the first stratigraphic excavations at Uaxactun in 1928; and during the past winter he came to Yucatan to confer with Mr. Roberts upon the development of the latter's investigations.

Mr. Roberts began his work by reviewing thoroughly with Dr. Vaillant the collections in storage at field headquarters. He then searched for places at Chichen Itzá where rubbish would most likely have accumulated, selecting for trial excavation the deep depression of a "dead" *cenote,* or natural sink-hole, which lies close to the Monjas and several other important buildings. In the bottom of the *cenote* there was located and sectioned with trenches a deposit of from 7 to 12 feet in depth. The strata were not always clearly marked, but it was possible to determine four certain and three probable layers of superimposition, and to collect from them a large amount of sherd material for type studies and stratistical analysis.

Although the data have not as yet been thoroughly digested, certain important results are already apparent. The dead *cenotes* were repositories for rubbish; the deposits in them accumulated with sufficient slowness to insure their reliability in determining sequence of wares and styles; and the tentative classification worked out by Dr. Vaillant has been proved valid.

Both Dr. Vaillant and Mr. Roberts believe that the objectives of future work should be specific rather than general. The subject is an enormous one. Museum materials are scanty and, as a rule, poorly identified as to place of origin. Dr. Vaillant has already derived about as much information as can now be gathered from study of existing collections, and his conclusions, although unpublished, have most generously been placed at Mr. Roberts' disposal. They therefore advocate a series of intensive field investigations in certain regions which appear to have been centers of pottery development. Stratigraphic excavation at sites in such areas should provide both new data and a knowledge of the sequence of styles which will render understandable many now practically valueless museum specimens. Northern Yucatan is recommended for prior consideration and Chichen Itzá as point of first attack, thus permitting close correlation between the ceramic, architectural and other researches. In addition to excavation, Mr. Roberts will continue studies begun in 1930 of local clays, and of modern Yucatecan methods of pottery making. He hopes also to supplement observation of the more obvious characteristics of ancient and modern pottery by chemical and microscopic analyses similar to those used with such success in South America by Dr. Linné of Sweden.

Dr. Morley's work on the hieroglyphs has progressed steadily; the second section of his compendious presentation of all known dated monuments is approaching completion. The first, under the title *The Inscriptions at Copan,* appeared in 1920. The present book covers the Peten; and the third number of the trilogy will include the dates from the rest of the Maya area. These volumes contain exhaustive analytical and comparative descriptions of texts and discussion of their bearing upon all aspects of Maya history. The fact that they also bring together the entire corpus of data now available gives them rank as prime sources for all future work in the field of Maya epigraphy.

Closely allied with Dr. Morley's work is that of Dr. John Teeple on the hieroglyphic inscriptions. For the past two years Dr. Teeple has been a Research Associate of the Institution in Middle American Archeology and the results of his studies have been published during the current year under title of *Maya Astronomy* (Pub. No. 403). He has shown conclusively that lunar phenomena form a large part of the record in the Maya inscriptions and that the age of the moon, *i.e.* distance from the new moon at any given moment, was always a matter of great importance. The different methods of numbering the lunar months, while at first numerous, suddenly crystallized in 9.12.15.0.0 of the Maya Chronological Era (428 A. D. in Dr. Morley's correlation of Maya and Christian Chronology) into a Uniform System which was used throughout the Old Empire. Seventy years later astronomer-priests at the city of Copan discovered the eclipse syzygy, and from this time on one by one the cities of the Old Empire gradually fell away from the Uniform System, each adopting a system of its own, which resulted in general confusion. Important as are Dr. Teeple's contributions to the more restricted field of Maya astronomy, they are already overshadowed by their larger historical implications, as indicating the diverse cultural elements at work within the Old Empire. It is confidently to be anticipated that further investigations along the same line will shed additional light on the Old Empire period, the Golden Age of the Maya civilization.

An offshoot of the Chichen Itzá project has been the exploration of Cobá, a ruined city in the eastern part of northern Yucatan. Cobá was heard of by the American explorer, John L. Stephens, in 1841, but was not visited by him. Later, presumably in the 90's, Teobert Maler was at Cobá, as is evidenced by some photographs by him of its buildings preserved in the museum at Merida. He made no report, however, and the actual opening up of the city was only accomplished in 1925, when Dr. Morley organized a series of expeditions for its exploration and study. These proved Cobá to have been not only a very large and important center in late times, but to contain hieroglyphic inscriptions indicating its occupancy at an unexpectedly early period of the Old Empire. Further work, therefore, promises to throw light on the whole problem of the colonization of Yucatan from the Peten, and data may well be recovered upon the still very imperfectly understood era between the break-up of the Old Empire and the Renaissance.

Mr. Eric Thompson of the Field Museum, who as a member of the Chichen Itzá staff took part in the 1925 expeditions, offered during his vacation in the winter of 1930 to conduct new explorations for the Institution at Cobá. With Mr. Pollock he spent several weeks there. Materials for a map were gathered, architecture was studied, and particular attention was devoted to a remarkable series of paved roads or causeways which radiate from Cobá in all directions.

Mr. Thompson reports as salient discoveries a number of carved and plain stelæ, several new causeways, three of which were found to have actually crossed Lake Macanxoc, and two ball-courts of Old Empire type with sloping walls, but provided with stone rings—an interesting link between Old and New Empire courts.

The architecture of Cobá presents problems difficult of solution. There are many similarities to the Old Empire cities of northern Peten, but in some respects, notably the length and width of the rooms, certain of the structures are in advance of those of Peten. In addition, there are several buildings which indubitably belong to the late East Coast or Tulum style.

Mr. Thompson believes that Cobá, as a possible link between the cities of northern Peten on the one hand and Chichen Itzá and other sites of northwest Yucatan on the other, demands investigation. Comparative studies of pottery and of architecture would appear to offer the readiest means of approach to the problem. At a moderate cost it should not be difficult to obtain information on the pottery types, and possibly their sequence, at Cobá; and at the same time clear up certain outstanding architectural puzzles. Such work should be possible without large expense for plant, as it would not involve extensive excavation. Buildings need only be investigated sufficiently to settle definite architectural points, and no great outlay on repair would be required. Seaplanes, once the trees at the end of Lake Cobá had been cut down, should prove the best means of transport.

Mr. Thompson believes that when Cobá has yielded its quota of information on ceramics and architecture, Yaxuna, the terminus of the great causeway which runs westward from Cobá, could be carefully worked. This city was undoubtedly closely connected with Cobá both culturally and commercially, but it is only a scant 12 miles from Chichen Itzá. Some of the masonry of collapsed structures appears to be of early Cobá type, yet the only standing structure is built in the same style as the Monjas at Chichen Itzá. At Yaxuna, then, we should find Cobá ceramics, possibly merging into Chichen Itzá types, or even directly associated with Chichen Itzá types in circumstances that would permit the Cobá wares to be linked chronologically with those of Chichen Itzá on the one hand and with those of Peten on the other. In such manner, certain Chichen Itzá potteries might be dated in terms of the Old Empire. This in turn would facilitate isolation of pure Maya types, and so place us in better position to decide what elements at Chichen Itzá are attributable to Mexican influence and what are due to the merging of Maya and Nahua cultures.

Mention has been made of reconaissance digging at Tayasal on Lake Peten Itzá, the last independent Maya stronghold. During the field seasons of 1921 and 1922, Dr. Guthe, under an agreement with the Government of Guatemala, carried on excavations for the Institution at this site.

After the abandonment of Chichen Itzá about the middle of the Fifteenth Century, according to the early chroniclers, the Itzá migrated southward from Yucatan and established their capital at Tayasal on the shores of Lake Peten Itzá. The immediate object of Dr. Guthe's excavations was to ascertain whether proof of direct contact could be established from the material culture. Two distinct periods of occupation were traced: the earlier giving back to Old Empire times and probably contemporaneous with other sites on the shores of the lake—Flores and Ixlu for example—which flourished at the very close of the Old Empire, and the later Itzá reoccupation of the Fifteenth, Sixteenth and Seventeenth Centuries. While further work will have to be done at Tayasal before its connection with Chichen Itzá can be established by means of the excavated material, satisfactory corroboration of the Spanish descriptions of Tayasal at the time of the Conquest (1697) was obtained, and this project should be continued.

An important event of the year was Colonel Charles A. Lindbergh's cooperation with the Institution for reconnaissance of archeological areas by airplane. Becoming interested as result of observation of ruins in Yucatan during flights made early in 1929, Colonel Lindbergh offered his assistance to the Institution, and during the summer, at President Merriam's suggestion, he spent several days at the chairman's archeological camp at Pecos, New Mexico, making flights over the Canyon de Chelly, the Hopi country, Chaco Canyon and the Pajarito Plateau. The photographs of ruins and of topographic features secured at that time by Colonel and Mrs. Lindbergh demonstrated the great utility of the airplane as an agency for locating sites, and for determining their relation to water supply and arable land.

While Colonel Lindbergh was in New Mexico he discussed with the chairman the possibility of air exploration in the Maya country, and in October 1929, through the good offices of Pan American Airways, which supplied the plane and furnished ground facilities, five days' flying were carried out over British Honduras, Yucatan, Mexico, and the Department of the Peten, Guatemala. The primary purpose of the undertaking was to ascertain how much information as to a heavily forested region could be gathered from the air. The Central American jungles are so dense that not only is ground travel exceedingly slow and difficult, but ruins, even of large cities, often remain unknown even when well-traveled trails pass in their immediate neighborhood. Furthermore, it is almost impossible from the ground to get any proper idea of the country one is traversing because one is literally so engulfed in vegetation that distant views can never be obtained. Hence we have lacked much archeologically significant information as to the topography of the Maya area, its relief, its drainage systems and the distribution of swamp, savanna and forest.

The flights took place from Belize, British Honduras, Mrs. Lindbergh acting as photographer, Mr. Ricketson and the chairman alternating as observers. The first day's flight led up the Belize River to El Cayo, thence to the ruins of Tikal whose high temples, standing clear of the jungle, served as orientation point for setting a northward course. Tikal to Uaxactun, a hard day's trip on mule-back, was made in six minutes. While over the latter place, photographs were taken of the Institution's camp and the ruins. North of Uaxactun and south of the Yucatecan settlements lies a long stretch of uninhabited and mostly unexplored forest. This was crossed, the party spending the night at Merida. The following day, Colonel Lindbergh headed eastward to Chichen Itzá for photographs, then turned south and flew down the interior of the peninsula to Belize. The third day, Tikal and Uaxactun were revisited, a stop was made on Lake Peten Itzá, and the afternoon was devoted to a flight across the little known country behind the Cockscomb Mountains. On the fourth day there was explored the hinterland of the Yucatan east coast; and the morning of the fifth gave opportunity for study of the Cobá district.

Results were most satisfactory. Several hitherto unrecorded ruins were observed. It was found that after a little practise one was able to distinguish the mounds of the larger cities, even when they were covered with the heaviest sort of jungle. It was also possible to locate them with a fair degree of precision by such natural landmarks and compass bearings as would enable ground parties to reach them with much less difficulty than if they were "going blind." Most important of all, it became clear that not only major geographic features, but the details of forest-type distribution can readily be made out and plotted from the air. As different sorts of vegetation reflect varying soil conditions and rainfall, and as the latter factors were naturally of great importance in determining the regions best suited for occupancy by an agricultural race such as the Maya, it may readily be seen how much valuable knowledge could quickly be gathered by an intensive air survey. Also, in prosecution of biological, geological and other investigations the plane would be of much service in transporting small parties to the interior where they could be landed on lakes or the larger rivers. It is hoped that the Institution may be able in the not too distant future to avail itself of this method of carrying forward its work in the Maya country.

Exploration by land or in the air, hieroglyphic research, excavation, the study of architecture and of pottery—all these activities are purely archeological. No matter how carefully planned or how successfully carried out, they can only result in the attainment of limited objectives. For with the best of methods archeology can recover no more than the bare skeleton of the past; a skeleton, too, which is both fragmentary and disarticulate.

The archeologist in the field is primarily a fact-finder. In this he needs no help. When, however, he comes to interpret his discoveries, when he attempts to say what ruins and potsherds mean, he requires knowledge of all the multitudinous factors which through the ages have conditioned human existence and shaped human action. His case is like that of the paleontologist who would clothe with life the crushed bones from the fossil quarry. And, as does the paleontologist, he must infer from the effect that present environments and present happenings have on contemporary organisms, what he can of the action of similar phenomena in the past.

The archeologist is thus abruptly hailed from the comforting shade of his trenches to the glare of the existing world, and there he stands bewildered. He surveys the environment of today to find that its complexities are utterly beyond his power to comprehend. He looks at the very simplest of modern peoples; their life proves unbelievably involved. But if he be willing to face the situation and not pop mole-like back into his burrow, he will find that other sciences are grappling with the problems of plants and animals, of weather and rocks, of living men and existing social orders; collecting, classifying, winnowing detail, and gradually formulating the basic laws which render this perplexing universe understandable. Beside them and with them the archeologist must work if his results are to be more than the putterings of the antiquary.

All this is obvious enough; but surprisingly seldom have archeologists made serious attempts to ally themselves with other scientific men. Dr. Morley from the beginning has realized that the unraveling of Maya history demands such cooperation. Hence his insistence that the work in Yucatan should become the nucleus of a group of correlated researches, and that Chichen Itzá should be their first focal point. To make clear the bearings of studies now under way and to indicate what others should be added, it is necessary to list the outstanding categories of information that are needed.

In the first place, we should work from the present, which we know or can know, back to the as yet unknown past. Thus we are forced to examine the Maya of today, their physical structure, their psychology, their social and economic life, their language. We can also learn much of their career during the past four hundred years from study of the documentary history of Yucatan. Of conditions existing at the Conquest the earlier historical sources tell us many things. Passing from the Maya themselves to the environment which has, as with all people, been so potent a molding influence, we find that we need knowledge of the physiography and geology of Yucatan and of its climate; also of its flora and fauna.

The list of the archeologist's requirements reads like the contents table of an outline of science. And rightly so, for no single constituent of the cosmos fails to bear, in one way or another, upon human life. Some lines of investigation, however, are naturally of greater, or at least of more immediate, importance than others; and work along some of them already has begun. In the short descriptions which follow, the collateral researches are considered from the point of view of what they may be expected to reveal, directly or by inference, as to the history of the Maya. Each one, however, has extremely important problems of its own, and each bears significantly upon and meshes closely with all the others. Discussion of these interrelations can not be undertaken in this very general preliminary statement, both for lack of space and because it is believed that in future Year Book reports special studies can be handled more fully and more authoritatively by the men in actual charge of them.

The initial group of investigations concerns the living Maya, and logically first comes consideration of who and what the Maya are. These questions lie in the province of physical anthropology, the science which deals with the bodily structure of mankind. Answers are needed by the historian in order that he may judge of the origin of the Maya and of the degree of their relationship to other aborigines of Middle America. He wishes to know, for example, whether or not they are closely allied to the highland peoples from whom they seem to have derived the germs of their culture; whether they give evidence of racial homogeneity or of extensive crossing. Also, it is necessary to learn what admixture of Caucasian blood has taken place since the Conquest.

In 1927, Dr. George Williams, under joint auspices of Harvard University and Carnegie Institution, inaugurated the work by examining some eighteen hundred Yucatecans. He also conducted tests in basal metabolism and collected blood samples. The results are now being prepared for the press. It is obvious that the investigation should continue, and arrangements have been made with the Institution's Department of Genetics for Dr. Morris Steggerda to visit Yucatan the coming winter. Dr. Steggerda will make a preliminary survey of the field. He will also check, by remeasurement of some of the individuals originally examined, the work of Dr. Williams, in order to make sure that the methods of the two researches are similar and that their results will therefore be comparable.

Closely related to the researches in physical anthropology are those in medicine. No final appraisal of the bodily make-up of a people can be made without knowledge of the factors which control their health. Their material and intellectual accomplishment are presumably largely dependent upon their physical condition. The findings of medicine are essential for the study of modern social and economic conditions in Yucatan. Their value for the historical investigation, although less obvious, is also very great. It has, for example, been suggested by Spinden that the fall of the Old Empire may have been brought about by the wasting effect of endemic yellow fever. Whether or not this was the case must be settled by medical evidence. And even if this devastating disease should prove not to have been present in the New World in pre-Spanish times, other maladies—either virulent, such as syphilis, or subtle as are nutritional troubles—may have exercised deep influence upon the career of the Maya. Malaria, now the most harmful of all tropical diseases, may also have been present. To settle such points the archeologist-historian must have the cooperation of the student of medicine.

The original step in studying the health conditions of the modern Maya was the establishment at Chichen Itzá of a free clinic under the able direction of Miss Katherine MacKay, which for several years has served the towns supplying the project's workmen and which has come to be visited by Indians from all the surrounding country. The records of the clinic have provided a foundation for continued observation, and the friendly feeling inculcated among the natives has been of inestimable value in facilitating subsequent investigations, not only in medicine but in all lines requiring cooperation of the natives. The health survey of Yucatan was inaugurated in 1929 under joint auspices of the Department of Tropical Medicine of the School of Public Health of Harvard University and Carnegie Institution. It is under the direction of Dr. George C. Shattuck. Two winter seasons have been spent by Dr. Shattuck and his staff in the field.

They have made clinical examinations, have gathered statistics and have conducted specific studies of certain prevalent diseases. They have found the country, for the tropics, unusually healthy, but intestinal and respiratory troubles prove to be extremely common. Yucatan, according to Dr. Shattuck, is admirable territory for studying the very important and little understood tropical anemias, because malaria, which as a rule is so abundant and the symptoms of which overlie and becloud the more subtle manifestations of anemia in other regions, is here relatively rare and its effects can, in a general sense, be factored out. As a first step in this investigation, Dr. Shattuck has undertaken the determination of normal standards, to be followed by nutritional research, checks of the bacillary and amebic dysenteries and of other pertinent factors. Extension of the work will lead to consideration of the whole question of life in the tropics, involving the human geography of all tropical countries and the ability of various peoples to exist under conditions of heat and humidity. There are naturally involved matters of race, of climate, of food supply, of native and introduced diseases and of the physical properties of the sun and the atmosphere. So important does Dr. Shattuck regard this extension of the research that he is planning to devote the coming winter to a general study of what has been done by other investigators and to conferences with physicists, climatologists and nutritionists, whose present advice is essential and whose future cooperation must presumably be called for.

During the 1930 season the principal objectives of study were the basal metabolism of Maya Indians, their blood pressures and their blood pictures with special reference to anemia. This work was done at Chichen Itzá. In Valladolid, the relative prevalence of syphilis among Maya Indians and Yucatecans was the main objective. Data on blood pressure, anemia, malaria and other diseases were likewise obtained. Dr. Shattuck also demonstrated to Dr. Francis I. Procter at Chichen Itzá some cases of a chronic folliculitis which closely resembled tracoma, and which may ultimately prove to be a form of that disease. Dr. Procter is an occulist of large experience who has been actively interested for some years in tracoma among the Indians of the Southwestern United States. His interest in this eye disease of Yucatan resulted in the examination of school children and others in a number of places near Chichen Itzá and at Valladolid, with the result that it proved to be very prevalent.

The data collected by Dr. Shattuck and his associates in 1929 and 1930 will be more fully presented in a report now being prepared for publication.

From the beginning of the Chichen Itzá project it has been realized that studies would have to be made upon the social and economic life of the Maya of Yucatan. Only with thorough knowledge of the living people and of modern conditions can one utilize understandingly the documentary records of the post-Conquest period, and from them work still farther backward into prehistoric times. But like research in pottery, or physical anthropology, or medicine, the task of analyzing an existing population can not even be begun as a side-line or by-product of any other investigation. It requires special abilities and specialized methods. But particularly does it require that its development be shaped by a person of broad experience and wide interests, a man who can formulate and direct attacks upon the many concrete objective elements inherent in the social complex without losing sight of the deeper meanings which are masked under surface intricacies. Dr. Robert Redfield of the Department of Anthropology of the University of Chicago has been appointed leader of the survey, the University very generously allowing the Institution to avail itself of his services during a certain part of each year.

In 1930, Dr. Redfield spent three months in Yucatan. It was not the purpose of the trip to collect materials on any special ethnological topic or in any particular local community. He desired to take such a rapid general view as would permit him, first, to determine some of the problems suitable for study, and, second, to prepare a program of research. No systematic study was therefore made of the ethnology or folklore of the Maya, but sufficient information was secured to permit a judgment as to the character and range of culture in Yucatan. His time was about equally divided between the city and the country, between the civilization of Merida and that of the villages. About three weeks were spent in Merida. A trip was made to Hunucmá, in the northwestern part of Yucatan, and another to Sotuta and its environs, in the south central part. Because of the fact that Chichen Itzá was a convenient point of departure, and because the southeastern part of the state is changing more rapidly than other regions and is therefore more interesting, special attention was given to the Chichen Itzá district. Preliminary information was secured from the two villages most accessible to Chichen Itzá: Pisté and Xocenpich. About ten days were spent in Chankom, south of Chichen Itzá. In Tekom contact was made with Filomeno Pat, Indian leader, who offered to help representatives of the Carnegie Institution in making contact with the uncivilized Maya of the Territory of Quintana Roo.

As result of his observations, Dr. Redfield proposes that there be made a well-rounded study leading to a description of contemporary society in the Peninsula. The inhabitants are not the representatives of a single simple culture, for in Yucatan there is to be found the entire range of sophistication from primitive tribesmen to *Meridanos* educated in Paris or New York. Therefore the methods ordinarily employed by an ethnologist working among a primitive people are not alone adequate. The ethnologist may justly assume that the group he studies is a fair sample of a larger tribal culture. But in present-day Yucatan the community units are not self-sufficient. The institutions that control each community are in part shaped from without, and at the same time bound up within a larger, more inclusive society. It is this larger society which must be the object of study. A description of the folkways characterizing some selected village will not adequately describe Yucatecan life; it must be studied as a thing in itself. It is not suggested, however, that the community survey of the ethnological sort be abandoned. The mere study of the formal political or social institution from the point of view of a student working in Merida would fail to take into account the unwritten ways of the folk which still to a very great degree determine the behavior of the inhabitants of Yucatan. Community investigations must therefore be made. There will have to be more than one survey, because culture is not homogeneous in the Peninsula. But they should be carried on with constant reference to the larger society with which the village life is now inseparably associated.

Briefly, it is proposed that the project include two closely interrelated divisions. The first is a study of Yucatecan society, regarded as a single entity. This would be carried on with Merida as a base and would include within its consideration the life of that city, as well as the more explicit social, economic and political organization of the state. But one can not begin by grappling with the whole of Yucatan; the problem will have to be broken up into a series of special topics, each of which can be the object of research.

The second division of the program proposed by Dr. Redfield consists of several community studies, wherein attention will be directed to selected local communities. The studies will be "year-round" projects, of the sort commonly made by ethnologists, except that their purpose will be to record the culture of the community as it now is, not merely to report such unmodified native practises as remain. It is therefore proposed that in addition to the usual collection of folklore and items of local custom, the work comprise an accurate record of the round of life in its entire setting. This setting includes the larger Yucatecan society. It is therefore desirable that both divisions of the program be carried on at the same time, so that each, in referring to the other, may find suggestion and explanation. In 1931, Dr. Redfield will spend six months in Yucatan, undertaking the first steps of the more general study and selecting the communities best suited for special investigation. At the same time he will be on the lookout for properly qualified individuals to carry on, in future years, the unit studies.

Linguistic research, an integral part of the study of the living Maya, remains to be considered. Thorough investigation of the large and territorially wide-spread group of tongues constituting the Maya stock may confidently be expected to throw much light upon the broader linguistic problems of aboriginal America. This, and its bearing upon linguistic science as a whole, need not concern us here, as at the moment we are primarily interested in its application to specific questions of Maya history. Seen from that point of view, the work is of undoubted significance. First, comparative analysis of the different Maya dialects should permit judgment as to the amount of time which has elapsed since they ceased to form part of a single parent language, and as to the order and antiquity of their separation. Second, the study of vocabularies might possibly indicate, by common possession of terms for objects not found or activities no longer pursued in their present habitats, the nature of the country originally inhabited by the Maya. Third, knowledge of modern Maya is the first step toward ultimate reading of those parts of inscriptions which are not now decipherable. If Maya hieroglyphs had been pure picture-writing, language would, of course, not enter into attempts to read them. But there is every reason to suppose that they were partly phonetic, or at least that they expressed phonetic elements by a sort of rebus-writing He who would decipher the glyphs must, therefore, necessarily know Maya; perhaps not the Maya of today, nor possibly even the colloquial speech of the Old Empire. The glyphs, it may be, record an archaic, ceremonial language, as so many of our monuments perpetuate dead Latin. If so, the mere learning of modern Maya will not suffice, and the professional linguist will have to be called upon for reconstruction by comparative means of the Maya "Sanskrit."

What is hoped will be an intensive and long-time research upon the Maya languages was inaugurated during the past winter. Dr. Manuel J. Andrade came to Yucatan under the auspices of the Department of Anthropology of the University of Chicago, and using Chichen Itzá as headquarters devoted several months to Yucatecan Maya. Later in the season he visited the Huasteca, a tribe of northern Vera Cruz whose speech is Maya, but whose culture is un-Maya.

For the coming year the Department of Anthropology of the University of Chicago and Carnegie Institution are cooperating to enable Dr. Andrade to continue his investigation. He will go to British Honduras to study isolated Maya groups in that country and will later accompany Dr. Morley on an expedition to the Usumacintla River, where there are still living the Lacandones, a small remnant of the last of the truly wild Maya.

There have now been considered the projects in physical anthropology, in medicine, in sociology and in linguistics which have been undertaken to enable us to understand the Maya of today, and so to permit us to judge more accurately than would otherwise be possible of what the ancient Maya were and how they acted. The gap between the present and the prehistoric past must be bridged by study of the documentary history of the nearly four hundred years which have elapsed since the Conquest. Its direct relations to archeology are numerous and important The accounts of the conquerors and early ecclesiastics contain much detailed information as to the aboriginal condition of the Maya. They also make clear the methods worked out by the incoming Spaniards for the government and control of the native population, and so explain the basis upon which modern society rests. To make an extended investigation of the history of Yucatan, Dr. France Scholes, head of the Department of History of the University of New Mexico, will join the staff of the Institution in 1931 as a member of the Section of American History, giving, by arrangement with the University, half his time to the work.

Another documentary project shortly to be undertaken strikes even further into the past than does examination of the Spanish sources. It will consist of a collation of the Books of Chilam Balam. These were written by native Maya shortly after the Conquest. They are transcriptions, in the Latin character, of pre-existing historic records kept in hieroglyphic writing. The Books of Chilam Balam are of the utmost value, for they give in outline the events of the pre-Columbian period. Their time-counts also extend into the historic period, thus offering one category of evidence for correlating Maya and Christian chronology. The books have not fully been translated. This task will be completed and the various texts will be compared by Mr. Ralph Roys, who in 1931 will become a special investigator for the Section of American History.

It is important to know the racial makeup of the Maya, their present health, customs, and the events of their recent career. It is essential that we should learn from the ruins their distribution and their arts in the centuries before the Conquest. But the "hows" of all these things, to say nothing of the even more significant "whys," we can not grasp; in other words, we can not write history until we understand the environment which from the earliest times to the present day must have played so large a part in shaping the course of their existence.

Environmentally, the Maya country is far from uniform. The northern part of Yucatan is semi-arid subtropics, the Peten region is humid jungle, the highlands of Guatemala are temperate. There is almost every sort of country—desert, mountain, coastal swamp. And yet before we are through we must know the topography of all these regions, their rocks, their soils, their weather and the plants and animals which inhabit them. Such data are gradually being acquired by many agencies, but to combine them into comprehensible form as a background for either the biologist or the student of man requires the synthesizing methods of ecology. The common desire for a broad yet accurate grasp of conditions in a large and significant area has led to consideration of plans for association, in Middle American research, of the Department of Biology of the University of Michigan and the Carnegie Institution. The University is tentatively contemplating a general biological survey starting in Yucatan and eventually extending to other districts. The Institution hopes to undertake studies in geology. And jointly the two would strive to interest other groups in such investigations in physical geography and meteorology as are necessary to round out the picture.

Through the good offices of President Ruthven of the University of Michigan, who from the beginning has taken the keenest and most helpful interest in the project, Dr. F. M. Gaige came to Yucatan in the winter of 1930 for several weeks of reconnaissance. He reports that not only is there a vast amount of valuable work to be done in the mere cataloging of species, both of plants and animals, but that intensive studies of local distributions and of life histories, if carried out in the light of geological and meteorological knowledge, would open avenues of approach to some of the most fundamental problems of biology. Needless to say, the Institution would welcome warmly the entry of the University into this field and would do everything in its power to be of service in forwarding its direct program and in stimulating any collateral researches which would render it more effective.

It will by now have become evident that to carry the investigation of Maya prehistory, or any similar project of serious and comprehensive nature, to a successful issue, one must build up a whole complex of associated researches. But this is not easily done. One can not employ first-rate authorities in every branch of science nor, even were that possible, could one expect their best efforts if they considered their work a side-show, as it were, of archeology. There has to be give as well as take; definite benefits, both practical and intellectual, must be offered in order to induce institutions and individuals to throw themselves whole-heartedly into the field. Such advantages are believed, in the present case, to exist.

On the practical side, the Institution is already operating both in Mexico and in Guatemala; it has established friendly relations with federal, state and local authorities, and with the people. It has headquarters at Chichen Itzá, Uaxactun and Guatemala City The members of its staff are familiar with customs requirements, transportation facilities and bush conditions. Anyone who has operated off the beaten track in foreign countries can appreciate how such contacts and such sorts of information help in planning, budgetting, equipping and running an expedition.

Material considerations are, however, relatively much less important than the scientific profits which may be expected to accrue from cooperative endeavor. The botanist or the zoologist needs the data and the results of other workers fully as much as does the historian. No research can fail to go farther and to strike deeper if it be carried on in conjunction with other researches dealing with the same general body of facts. For example, the biologist studying the distribution of plants and animals in Yucatan should know the extent and approximate period of any wholesale deforestations which have occurred in the Peninsula. These data the archeologist working in connection with the agronomist will presumably be able to give him. The biologist, no less than the student of man, must understand the climate of the region and its geological history and make-up. Research workers in medicine, to take another instance, find it necessary to call on the archeologist for estimates of population density in former times; on the physical anthropologist for the racial constitution of the present population; on the biologist for the ranges, habits and life-histories of noxious organisms; upon the nutritionist for the nature of the food supply; upon the meteorologist for statistics as to seasonal fluctuations of the weather; upon the ethnologist for information as to the social practises which form so potent a factor in all problems of epidemiology. And so one might go on indefinitely, pointing out useful, even essential interlockings between the various sciences.

One other point. Field investigations as a rule lack continuity, particularly when prosecuted in foreign countries. Inaccessible regions are seen for brief periods; often they are visited but once. The result is that the student has the most fleeting glimpses of conditions which deserve long-continued observation; he acquires mere scraps of knowledge, when he should have full series of data. The all-important element of passing time can not properly be gaged, and so perspective is lost. Any opportunity, therefore, to work throughout the cycle of the seasons and to repeat and check observations over a period of years should, if possible, be seized.

The stations of the Institution are always open; the work in Middle America is expected to continue indefinitely. The field is almost untouched; it comprises every sort of environment. Participation in the survey, either directly or indirectly, would accordingly seem to give promise of sound and significant results in any one of the biological or geographical sciences.

The survey would also appear to offer occasion for a new type of coordinated research in the humanistic disciplines. The living Maya exemplify in the clearest way a number of most important historic and social phenomena. They present, for instance, a splendid example of what occurs when a dense native population comes under the influence of a small intruding group of superior culture. The same sort of thing has happened again and again throughout the course of history and in all lands. And it has been perhaps the strongest single force in shaping the development of the Latin American nations.

Viewing the New World by and large, we find that at the Conquest one of two things usually took place. Either the Indians were exterminated or they were not. Where, as in most parts of the United States and of eastern South America, the aborigines were few and of rude culture they quickly disappeared. In Middle America and western South America, however, the native populations were dense and relatively civilized. What might have happened had the discovery been delayed but a few centuries, and the Aztec and Inca states been given time to expand, to stiffen, and to weld themselves together, forms fascinating food for speculation. The whole course of world events would doubtless have been changed. But the Spanish came, the flimsy political structures of Mexico and Peru fell apart, the nations were intellectually decapitated by the destruction of the small theocratic upper classes, in whom resided all power and all learning; and there were left the teeming millions which from the Sixteenth Century on have formed the body of the population. They have influenced the Caucasian immigrants quite as much as the latter have affected them. The social system and government of great areas in Latin America are the outcome of the blending of the two groups. Analysis of the interplay of racial and cultural forces, past and present, is essential to understand conditions in those countries; and knowledge of what has there occurred will supply invaluable material for the scientific study of often more complex, but fundamentally not dissimilar, conditions produced by military adventure and colonization in other parts of the world.

This matter of racial and cultural adjustments is surely one of the most portentous which faces us today. We have abolished space, and we are busily engaged in veneering western material civilization and ideas over the entire face of the globe. The resultant clash is responsible, at bottom, for much of what is now happening in China, in India, in Egypt, in South Africa, even in Russia. It appears, indeed, not unlikely that the historian of the future will see in these phenomena as great significance for the formation of his world as he can observe in the politics, say, of Nineteenth Century Europe. Yet to the details of that period a hundred scholars now devote their lives for every one who considers such fundamental ethnic relationships as are illustrated by the contact of the Indian and the Caucasian.

Research upon this particular phase of inter-racial contact lies, it is true, in the domain of the Americanist, and its immediate problems are essentially American. But it has world-wide implications, and it is of vital importance to the entire range of the sciences of man. The study is of appalling intricacy because it deals with human beings, and it is therefore beset with the multitudinous psychological bafflements, biological obscurities and gaps in the historic record which render the consideration of mankind so much more complex than any other research can possibly be.

Such inherent difficulties are, of course, largely responsible for the slow development of humanistic as compared to biological knowledge, and for its snail-like progress when contrasted with the rapid advance of the physical sciences. But students of man have also been culpable in failing to face the issue. Daunted by the awesome bulk of human history, or human evolution, or the nature of man, or whatever one chooses to call it, and shrinking before the grievous magnitude and the seemingly endless ramifications of their task, they have buried their heads, ostrich-like, in the comfortable sand-heaps of specialization.

Specialization, of course, is necessary, for it is the splitting up of something too large for immediate comprehension in its entirety to permit intensive consideration of its parts. The process, however, implies eventual reassembly of those parts and ultimate visualization of the whole. But each of the many sections, the so-called disciplines, into which the study of man has perforce been subdivided pursues its own ends with almost deliberate disregard of the objectives of every other. And within the disciplines, each worker or group of workers does practically the same. We have, of course, realized the dangers of intellectual isolation and we have attempted to counteract them by broadening the scope of graduate instruction, by holding mixed conventions, by establishing academies and research councils. Although such moves are certainly in the right direction, they are at best mechanistic set-ups rather than natural cooperations; and in our individual researches, our field, or laboratory, or archive investigations, in those activities which are nearest our hearts and to which our best efforts inevitably are given, we have made few and but half-hearted attempts toward real association or mutual understanding.

Forced cooperation is certainly not desirable. At best it is pretty sure to be artificial and therefore unproductive. But some form of cooperation becomes essential as the humanistic sciences broaden their outlook and deepen their researches, and there begin to be encountered phenomena too great for comprehension by any single group, yet involving principles of fundamental importance to all groups: race, for example; or environment *versus* heredity; or the inherent ability of mankind to increase its capacity for understanding. These things must be attacked and their underlying problems must be formulated if the study of man is to go forward.

But how? Every scholar is fully occupied with his own researches, every 'ology has its own preoccupations. In the few cases, however, where forces have been joined and the efforts of workers in several disciplines have in one way or another been brought to bear upon a single body of significant data, or upon any one important general problem, it has always resulted that not only was the gathering and digestion of specialized information in no way retarded, but that there has come about an interchange of ideas, an intellectual cross-fertilization, immensely valuable for all participants. Such investigations have, however, been the exception rather than the rule, and for some reason, possibly from mere inertia, perhaps because certain enterprises have been over-organized or their programs too rigidly defined, they have not yet become by any means standard practise in the social sciences. Further experiment is necessary.

The survey of Yucatan is being planned with the above considerations in mind. It is based on the theory that we should concentrate, whenever we can, upon fields where specialized researches can be pursued in entire independence of each other, but where results will be cumulative and findings comparable; and where common interest, if nothing else, will foster intellectual and practical cooperation.

The general problem toward the solution of which the investigation is directed may be formulated as follows: "What are the results of the meeting of two races of diverse physical make-up and differing culture?" This, as has been intimated, is a matter of very great moment. No research in history, anthropology, sociology, government, religion, genetics, esthetics, can be pushed very extensively or very profoundly without encountering one aspect or another of race or culture crossing. It is a problem transcending adequate comprehension by any one group, therefore it is an ideal one for joint attack. Even so approached, however, it is still too great. One can not hope effectively to begin a study of ethnic contacts with the whole world as a field and throughout the millenia of history. We must pick a simple exemplification of the problem both in space and in time. The New World offers a splendid laboratory for the study of culture growth, and the post-Columbian period in Latin America illustrates particularly well all the phenomena incident to the meeting of diverse peoples. But Latin America, again, is too big. We should still further reduce our preliminary objective; and so we come to Yucatan.

The area of Yucatan is small; its environment is uniform. Natural barriers isolate it from continental Mexico. For upwards of a thousand years the peninsula was the seat of a high aboriginal culture. The Spanish conquest resulted in obliteration of the externals of native civilization, in the catholicizing of the Maya, and the reduction of the dense native population to serfdom. There took place the inevitable hybridizations, racial, religious, social and economic; there were the same strifes, uprisings, readjustments, with far-reaching effects upon both elements, which have occurred wherever the Spanish found themselves overlords of crowded Indian nations. Yucatan presents an epitome of historical events and present-day conditions in much of Latin America; and, to a less precise but still significant degree, it exemplifies what has happened at all periods and in all parts of the world when, after military conquest, the will of a potent minority is enforced upon a race of lower culture.

It has seemed wise to formulate, at this early stage of the survey, only a few general principles. Each unit of research should be intensive, employing the technical methods and striving for the special aims of its proper discipline; but there should constantly be kept in mind its ultimate bearing upon the basic question of race-contacts; and there should also be fostered an historical point of view, in other words, a consciousness of the time-relation of all phenomena. And, finally, by field conferences, such as the one held during the past winter at Chichen Itzá, and by meetings elsewhere, close personal and intellectual touch must be kept between all concerned.

There have already been discussed the archeological, historical, sociological and environmental units of the survey. And mention has been made of other desirable researches. The difficulty lies not in what to do, but in selecting what is most important to do, in deciding how best to do it, and in finding the men and the means with which to get it done. No one institution can possibly handle a project so large and so varied. If ultimate success is to be attained it must come through realization by many agencies that the field is a significant one, through confidence that it is being developed in the proper way and through belief that investment of effort in cooperative research will bring valuable scientific dividends.

SOUTHWESTERN STUDIES

In the general statement regarding the activities of the Section of Early American History it was said that the Maya exemplify a high aboriginal culture and that the Indians of the Southwest throw light upon the early phases of agricultural civilization. In the Southwest which, archeologically speaking, comprises the states of Utah, Arizona, New Mexico and Colorado, with some territory in Nevada and in northern Mexico, there lived, long before the time of Christ, a scattering of semi-nomadic people who eked out an existence on the scanty game and the meager roots and seeds of the arid, almost desert country which they inhabited. By some means not yet understood they acquired corn and the knowledge of how to plant and care for it. Our first definite glimpse of them comes at this period. Finds made in the lower levels of dry caves frequented for shelter and used for burial reveal the Early Basket Makers, as they are called for want of a better term, just emerging from their former wandering hunting life. They had as yet no houses worthy of the name, nor even any pottery. But the fruits of their still tentative and unorganized farming were evidently bringing leisure for the perfection of their arts, and the care of growing crops and garnered harvests was evidently tying them more solidly to favorable parts of their range.

Increased ease of living stimulated progress. In the same caves that shelter the oldest remains, but at a higher level, lie the first crude houses of the Late Basket Makers, direct descendants of the Early Basket Makers, but now beginning to assume the first attributes of a settled people. They had discovered for themselves or learned from Mexico the art of pottery making; their dwellings were permanent; population was increasing and was coagulating into definite and, it must be supposed, ordered communities. The period of the Late Basket Makers seems to have been a long one; at all events its remains are abundant. And before its close there had been achieved the beginnings, at least, of practically all the lines of industry, and all the major social and religious devices which were taken over and carried to higher development by the Pueblos.

The Pueblos, the new broad-headed race which now entered the Southwest, destroyed, or crowded out, or absorbed the Basket Makers. They seem, however, to have brought very little with them, and to have accepted almost in toto the way of life already worked out by their predecessors. The first, or Pueblo I, period opened about the beginning of the Christian era. It would hardly be possible to distinguish its remains from those of the Late Basket Makers were it not for the change in head-form and for certain ceramic details. The culture, as it was to be elaborated and perfected in the subsequent Pueblo periods, was already in possession of its most essential traits, and had received the peculiar Southwestern stamp which distinguished it throughout the next two thousand years.

The course of Pueblo history can here be sketched only in barest outline. Population increased and much new country was occupied. Then came pressure by invaders causing loss of territory but forcing concentrations of people and stimulating cooperative efforts which resulted in the building of the cliff-houses of the Mesa Verde and the enormous pueblos of Chaco Canyon. This was the Great or Pueblo III Period. It lasted until about the year 1200 A.D., when it was brought to a close, apparently by a combination of drought and the attacks of nomads; and the Pueblos were still struggling to reestablish themselves in new regions when the Spanish conquest put an end to independent native development.

The Southwest saw no such brilliance as was achieved by the Maya and other Middle Americans. But in a way its growth seems to have been a healthier one. The far from fertile Pueblo country permitted no great accumulation of surplus wealth; hence life remained democratic and there never arose the aristocracies and priesthoods which so crushingly burdened the southern nations. One has the feeling that if the Spanish had not come, the Pueblos would eventually have triumphed over their difficulties and have gone on to even higher attainment. But that is beside the point. What is important to the student of the history of culture is the fact that the career of the Southwesterners exemplifies with extraordinary clearness the rise of a people, through agriculture, from nomadic savagery to a relatively high degree of civilization. And the process was carried on in an arid region.

All civilizations have been based on agriculture, and all of them appear to have had their ultimate origins in dry countries. The vitally important early stages of most civilizations, both in the Old World and the New, are, however, lost beyond hope of more than the most fragmentary recovery. But in the Southwest, remains are abundant and, thanks to dry air and sheltering caves, are often unbelievably well preserved. They can also be dated relatively to each other on the sure basis of stratigraphy, and the researches of Dr. Douglass on the annual growth-rings of trees used in house-building are giving us an actual chronology that already reaches back into the first millennium and may well be carried even further. Conditions in the Southwest are therefore perfect for following out in the greatest detail, and with high assurance of historic accuracy, the career of a nascent agricultural civilization. The results will not only be of interest in themselves, but will supply us with facts and with methods of great value in the attempt which must be made to read the much more incomplete record of similar happenings in other parts of the world. Particularly will this knowledge be of service for attack upon the beginnings of culture in the Middle American highlands.

The Institution's Southwestern work is being carried on by Mr. Morris and the chairman. Mr. Morris's whole early career was devoted to research in the Southwestern field. Also, during the summers of the years of his association with the Chichen Itzá project he continued to explore and excavate, the Institution cooperating with the American Museum of Natural History and the University of Colorado. From the caves of Canyon del Muerto, Arizona, and from open sites in the La Plata region in New Mexico and Colorado, he has accumulated a great mass of material and of information regarding the Late Basket Makers, the people who, it will be remembered, laid the foundations of Pueblo culture. Mr. Morris's data are being assembled and prepared for publication, in order to clear the deck for renewed field attack, the specific objective of which will be an attempt to bridge the important and baffling gap which now exists in our information as to the period between terminal Basket Maker and fully developed Pueblo. During the time covered by this report, Mr. Morris completed his manuscript on the Temple of the Warriors. In the summer of 1929 he explored the Grand Gulch region of southeastern Utah as a member of the Bernheimer Expedition of the American Museum of Natural History and excavated in Canyon del Muerto and in the Hopi country. The entire winter of 1929–30 he spent in study and description of his Late Basket Maker collections.

The chairman has been engaged in administrative duties incident to organization of the Division, and in writing. For fifteen years before joining the staff of Carnegie Institution he conducted excavations for Phillips Academy, Andover, at the Pueblo ruin of Pecos in New Mexico, special emphasis being laid upon development of stratigraphic methods. The results are still for the most part unpublished. As they represent the fruit of a long period of field activity, and also embody important data upon the later phases of Pueblo culture, an arrangement has been made under which he is working on the Pecos materials as a joint project of Carnegie Institution and Phillips Academy. When the reports have been issued he plans to continue study of Pueblo remains of the upper prehistoric horizons, paying particular attention to the interrelation of the specialized subcultures. His work will interlock very closely with that of Mr. Morris; and together they hope ultimately to undertake a series of technological comparisons which are much needed for accurate delimitation both of the chronological periods and the culture areas of the Southwest.

SECTION OF MODERN AMERICAN HISTORY

In December 1929, the former Department of Historical Research became part of the Division of Historical Research under the title of Section of Modern American History.

In the Year Book for 1928–29 there were stressed the invaluable services to the Institution and to history of Dr. J. Franklin Jameson, who for twenty-three years acted as director of the Department. His personal contributions as author, administrator, educator and editor need not be recapitulated, for they are familiar to all who have followed the progress of historical research during the past forty years. But it is desirable, at this time of reorganization, to hold firmly in mind the necessity of maintaining unbroken the traditions of intellectual honesty, sound scholarship and self-sacrificing devotion to the highest principles of research which characterized Dr. Jameson's régime.

The Section carries on the work of the Department in the preparation of publications designed to make available to investigators the source-materials of American history. It is also planning certain studies of Latin American and Maya history. Reports of progress on the major projects of research are presented below. At the close of the year (June 30) two volumes emanating from the Section were on the verge of publication: the third volume of Dr. Stock's *Proceedings and Debates of British Parliaments;* and the first volume of Miss Donnan's *Documents Illustrative of the History of the Slave Trade to America.* There has also been sent to press the fifth volume of the Jackson correspondence. The annual list of doctoral dissertations in history was issued as usual. Dr. Jameson has throughout the year always been ready to assist in advancing the work of the Section, and he has generously devoted much time and attention to the forwarding of undertakings that were commenced under his direction, particularly to the editing and proofreading of the fifth volume of the Jackson correspondence. Miss Pierce, while serving as secretary of the entire Division, has devoted especial attention during the year to putting the publications of the Section through the press and her principal labors have been those of copy editor and proofreader.

Dr. Leland continues to act as adviser to the Section in regard to current activities and to take part in the formulation of plans for the future. Although on leave of absence, he is able to spend some time of nearly every week in the offices of the Section and has completed reading the page proof of his first volume of the *Guide to Materials for American History in the Libraries and Archives of Paris.* During a short stay in Paris in the spring he was able to refer back to the original manuscripts in dealing with various queries that had arisen, and to collate certain diplomatic documents needed in the volume of treaties now in preparation. While abroad he also attended the annual meeting, in England, of the International Committee of Historical Sciences, of which he is treasurer, and the meetings, in Brussels, of the International Union of Academies, of which he is vice-president. In March he lectured before the Catholic University of America on the progress of international intellectual cooperation since the war. In June he represented the Carnegie Institution upon the occasion of the inauguration of the new buildings of the University of Brussels, and since January has served as chairman of the Institution's committee on lectures.

Dr. Burnett has written several biographical sketches, all of members of the Continental Congress, for the *Dictionary of American Biography*. He has, besides, been requested by the editor of the *Dictionary*, Dr. Allen Johnson, to serve that publication in an advisory capacity in so far as regards members of the Continental Congress. Activities of Dr. Stock included editorial services for the *Historical Outlook* and the *Catholic Historical Review*, and bibliographical work for the American Council of Learned Societies. For the year 1929 he was president of the American Catholic Historical Association, and again acted as chairman of the Committee on Publications of the American Historical Association. A course of six lectures was given before the students of St. Joseph's College, Emmitsburg, Maryland. Dr. Paullin has continued to serve as adviser to the *Dictionary of American Biography* and as treasurer of the Naval Historical Foundation. He has been appointed a member of the Advisory Committee to the George Washington Bicentennial Commission, on the Geographical and Topographical Relations of George Washington, and is also a member of the Advisory Committee on the Atlas of Hispanic America. In March 1930, he read a paper before the Columbia Historical Society on "Washington City and the Old Navy." In August 1929, he attended at New Haven, Connecticut, the conference on a Proposed Linguistic Atlas of the United States and Canada, and in December the annual meeting of the American Historical Association at Durham, North Carolina.

In October 1929, the Section moved from the quarters in the Woodward Building, which it had occupied for seventeen years, to rooms in the new Tower Building, at 14th and K Streets, which it shares with the Administration of the Section. At the same time the American Historical Review and the American Historical Association, which for many years had had their offices with those of the Section, moved to separate headquarters, at 40 B Street, S. W., within easy reach of the Library of Congress, where the present Managing Editor of the Review, Professor H. E. Bourne, is Consultant in European History.

Letters of Members of the Continental Congress, by Edmund C. Burnett

The character and contents of volume V of *Letters of Members of the Continental Congress* were in some measure set forth in the last annual report. The work of editing those materials has not yet been completed, but it is expected that the volume will be ready for the press in the autumn. Fortunately, just as the year is closing, it has become possible to include in the volume a considerable number of valuable letters which had not hitherto been accessible. Some of these additions are from the papers of General Nathanael Greene, others from the papers of Sir Henry Clinton, and both groups have been obtained through the courtesy of Mr. William L. Clements of Bay City, Michigan, the present owner of the papers. Extracts more or less brief and quite unsatisfactory for the purposes of this series from a few of the letters in the Greene papers had been found in print, as had also texts (as printed in Rivington's Royal Gazette) of a few of those among the Clinton Papers (the latter group being of course letters intercepted by the British); but not all of them by any means have ever appeared in print, and, in any case, it is gratifying to be able to obtain complete and accurate texts from the originals.

It has not been found necessary during the past year to go out of Washington in the interest of this series, inasmuch as it has been possible to obtain through correspondence such additional material belonging to the period of this volume as had come to light; but it is the editor's conviction that for the succeeding volumes it will be advantageous that he examine personally those papers in a number of repositories which have been acquired since the searches conducted several years ago.

Proceedings and Debates of the British Parliaments respecting North America, by Leo F. Stock

Most of the past year was employed in putting through the press volume III of the *Proceedings and Debates of the British Parliaments respecting North America.* For this volume of 571 pages, now being printed, the contents of which were described in last year's report, an introduction of about 11,000 words was prepared and the usual last-minute checking, corrections and additions made. The work of assembling and annotating the text for volume IV has been carried forward to 1730. It is as yet impossible to state at what year this next volume will end.

During the year, through the efforts of Dr. Jameson and the assistance of Miss Ruth Fisher, much additional manuscript material, for the period 1764–1777, to be printed for the first time in this series, was obtained from London. Practically everything from the Manuscripts of the House of Lords of value to future volumes has now been photographed for the Division of Manuscripts of the Library of Congress; its present accessibility will be of great help to the editor.

European Treaties bearing on the History of the United States and its Dependencies, by Charles O. Paullin

The manuscript of the third volume of *European Treaties bearing on the History of the United States and its Dependencies,* the materials for which with the exception of a few additional treaties were assembled and edited by Miss Davenport, is now being prepared for publication by Dr. J. F. Jameson. New materials for the fourth and final volume have been photostated in London, Paris, Lisbon, Vienna, Copenhagen and the Hague, and the preliminary steps for a search in the archives of Madrid have been taken. Miss Florence Spofford, an expert in the deciphering of old manuscripts, has continued the work of typing the photostats, under the direction of Dr. Paullin, who has collated and annotated all typed treaties. Among the noteworthy series of treaties included in the fourth volume is one between Great Britain and the small German states (Brunswick, Hesse-Cassel, Hesse-Hanau, Waldeck, Brandenburg-Anspach and Anhalt-Zerbst) covering the years 1776–1778 and providing for the employment of mercenary troops in America. The treaties in Spanish have been translated by Dr. James Alexander Robertson of the Florida State Historical Society, and those in Latin and Portuguese by Mr. C. K. Jones of the Library of Congress and the George Washington University. Dr. Paullin has assisted the secretary of the Division in preparing for publication volume V of the *Correspondence of Andrew Jackson.*

Judicial Cases concerning American Slavery and the Negro, by Helen T. Catterall

The Alabama and Mississippi excerpts have been finished and work has begun on those from the Louisiana Reports.

The courts of both Alabama and Mississippi are, down to 1859, more favorable to the cause of freedom than the Georgia Supreme Court. Whether the testator used the order, "remove and set free" or "set free and remove," was indifferent to them. Judge Clayton of Mississippi declares: "The mere collocation of words, if their meaning be the same, can not vary their construction. The right to freedom under the will is inchoate, and becomes complete, when the subjects of it are removed."

While the rule *"partus sequitur ventrem"* was rigidly applied in most of the slaveholding states, the Supreme Court of Alabama held, in two remarkable cases, "that all the incidents of the mother's condition at the birth of the child do not invariably attach to the offspring." Though the mother fled from Virginia to Kentucky, her children born thereafter were not "fugitive slaves" and the fugitive slave act of 1793 could not be invoked to recover them. The court also held that a child born in Indiana of a slave mother who was liable for her owner's debts, contracted before he removed her from Alabama, was not subject to be levied on when they returned.

The free negro appears to have flourished in Alabama. One rented a house, using the lower rooms as a barber's shop and the upper "in experimenting, and attempting to learn the art of taking daguerreotypes." After he "had abandoned the attempt to learn the daguerrean art," his dark room was used appropriately by ten or twelve white men for surreptitious gambling. Another, of mixed blood, held the office of constable, and a white man was indicted for offering resistance to arrest at his hands. The court decided that his pedigree could not be called in question.

The doctrine of "states' rights" proved a two-edged sword in the hands of Chief Justice A. J. Walker of Alabama. He gave an opinion in 1863, that an Alabama court had no more right to obstruct the execution of the confederate conscript act than a Wisconsin court "to thwart the execution of the fugitive-slave law in that State" This decision was overruled in a later case of the same term, the chief justice dissenting in an opinion of twenty-eight pages. He sorrowfully ejaculates: *"Tempora mutantur, nos et mutamur in illis."*

Many of the Mississippi cases have to do with the conflict of decisions by her highest court and by the Supreme Court of the United States as to the construction of the clause in her constitution of 1832 which prohibited the introduction of slaves as merchandise, or for sale after May 1, 1833. The Mississippi court held over and over again that the clause prohibited *proprio vigore,* while the Supreme Court of the United States persisted, down to 1851, in adhering to its contrary decision in Groves *v.* Slaughter. The prohibitory clause in the constitution was finally superseded by the amendment of 1844–46, which gave the legislature power to regulate the introduction of slaves, on which it promptly acted.

From 1840 to 1859, the courts of Mississippi held consistently that "Mississippi has no concern with the question of manumitting slaves elsewhere than within her own limits." In the latter year the court decided, in Mitchell *v.* Wells, that "it *now is* and *ever has been,* the policy of Mississippi . . . to prevent emancipation generally of Mississippi slaves . . . comity is terminated by Ohio, in the very act of degrading herself . . . by the offensive association" with free negroes. Consequently, a slave who had been taken by her white father to Ohio in 1846 and domiciliated there was denied the right "to acquire, hold, or sue for" the watch, bed and money bequeathed to her by her father in Mississippi. Judge Handy dissented in an opinion of twenty-four pages, and his views prevailed in 1871.

The Supreme Court of Alabama decided in 1867 that slavery had been abolished in that state "by the act of war—the occupation of the state by a federal army in May 1865." The judges of reconstruction days made some fine-spun distinctions in regard to this matter; but even in respect to them they did not concur unanimously. The High Court of Errors and Appeals of Mississippi held in 1867 that the constitutional convention of August 1865 abolished slavery within the state; but this decision was overruled in 1870, the court holding that freedom is personal to each particular slave—a question of fact in the individual case or as to localities. This decision was followed in 1872, when the court held that, even though Cowan's plantation was, at his death in April 1864, "not inside the picket lines of either of the forces," freedom had "long before" come permanently to his slaves, for that locality "remained subject to the general control . . . of the federal authorities." Consequently, his slaves had the capacity at his death to take his entire residuary estate which he had bequeathed to them, and they were "discharged of the necessity of removing to Liberia," as provided in the will; for such removal was held to be merely "a mode of giving freedom, a pre-requisite imposed" "by a prior law since abrogated."

It is gratifying to know that two authors of recent works dealing with slavery, one principally, the other incidentally, changed certain statements in their texts after their attention was called to excerpts in this collection which contradicted their assertions.

SECTION OF THE HISTORY OF SCIENCE

The great importance of the work upon the history of science by Dr. George Sarton, and the desirability of bringing it into close relation to other studies upon the intellectual evolution of mankind, led to the formation of the Section and its incorporation in the Division of Historical Research. At present its membership consists of Dr. Sarton and his group; Dr. E. A. Lowe, Associate in Paleography; and Dr. W. A. Heidel, Research Associate in Philosophy.

As a distinct discipline, or ordered category of knowledge, the history of science may be said to have been founded by Dr. Sarton, for until he attacked the subject as a life work it had for the most part been treated either superficially by dilettanti or narrowly by scientific specialists who, no matter how distinguished in their proper lines, were insufficiently grounded in most or all others; who ordinarily lacked a definite historical sense; and who were likely to be as casual in their historical recreations as they were critical in their own scientific researches. In consequence, contributions were scattering and incoherent; there were general treatises which were unsound, and solid productions of restricted scope and limited viewpoint. No group of scholars concerned itself with the whole complex of philosophical achievement that has made possible the material progress and the spiritual growth of the human race.

To make a start at tilling so enormous a field it was necessary: first, to establish a periodical to serve as repository for current studies, for critical discussion of sources, and for the listing of bibliography; second, to begin preparation of a preliminary outline of intellectual evolution in all lands and throughout the ages. The initial step was taken by Dr. Sarton in 1912, while still resident in Belgium, through the founding of the periodical *Isis*. Planning of the outline had already commenced, materials were constantly being gathered; and after the interruption of the war and Dr. Sarton's coming to America and his association with Carnegie Institution, he completed, and in 1927 brought out, the first volume of his *Introduction to the History and Philosophy of Science,* dealing with Greek and Roman science and with mediæval science to the end of the Eleventh Century.

The headquarters of the Section are at Widener Library, Harvard University, and the excellent bibliographic facilities of Cambridge and Boston are indispensable for carrying on the research. Dr. Sarton, as Lecturer in the university, is also able to supplement his written contributions and further stimulate the growth of the discipline by direct instruction of students. Dr. Alexander Pogo was appointed Fellow of the Institution in July 1929, to assist in organizing the data concerning the Sixteenth Century. Miss Mary C. Welborn will join the group in the autumn of the present year.

The twelfth annual report of Dr. Sarton covering the period July 1, 1929, to June 30, 1930 follows (previous reports appear in Year Books Nos. 18–28). It is planned that in future Year Books Dr. Sarton and members of this staff will discuss specific aspects of their work.

1. *Introduction to the History and Philosophy of Science*—The final redaction of volume II dealing with the Twelfth and Thirteenth Centuries

(From Rabbi ben Ezra to Roger Bacon) is almost completed. The manuscript will be ready this summer, and the volume will appear in the spring of 1931.

Considerable material, much of it in an advanced stage of elaboration, has already been accumulated for volumes III and IV, dealing respectively with the Fourteenth and Fifteenth Centuries. Miss Welborn will help to investigate more deeply some of the Latin documents; her work will begin on October 1, 1930.

In the meanwhile, Dr. Pogo is preparing materials for volume V, dealing with the Sixteenth Century. He has compiled a preliminary checklist of Sixteenth Century scientists and has devoted his attention thus far to the Portuguese, Spanish and Italian navigators and cosmographers.

2. *Other investigations*—Dr. Pogo has prepared a critical edition of the anonymous *La conquista del Peru* (Seville, April 1534), which is the earliest detailed account of the Spanish conquest of Peru, and of the *Libro ultimo del summario delle Indie occidentali* (Venice, October 1534). The latter will be published this summer by the American Academy of Arts and Sciences (vol. 64, 177–286, 1930). He has also made a study of the astronomical knowledge of the Egyptians of the Eighteenth Dynasty (to be published in Isis).

Dr. Jean Pelseneer of the University of Brussels, a Fellow of the C. R. B. Foundation, spent the academic year in my seminary. He is especially interested in the development of the mathematical and physical sciences in Newton's time.[1]

3. *Publication of Isis*—During the past year I have edited five numbers of Isis (39 to 43) forming the end of volume 12 (pages 451 to 588), volume 13 (604 pages), and the beginning of volume 14 (276 pages), a total of 1017 pages, 18 plates, 46 figures. They contain 23 papers, 61 shorter communications and reviews, and 2056 bibliographic notes. Dr. Pogo assisted in the editing of Isis.

4. *Lectures*—I gave my usual courses at Harvard University and Radcliffe College, and a few special lectures, to wit, one at the Connecticut College for Women and three at Brown University (Colver Lectures, April 1930). Dr. Pogo gave two illustrated talks on the history of astronomy at the Bond Astronomical Club, Harvard College Observatory

The report[1] of E. A. Lowe, Oxford, England, Associate in Paleography, is appended.

The year has been chiefly devoted to field work and reconnaissance, and much new material has been collected in the process. With the *Beneventan Script* finally out of the way, it has been possible to concentrate on the problems which surround Latin writing prior to the Ninth Century. Scientific investigation into the origins of our oldest Latin scripts and a comprehensive account of their history and development have not been attempted in the past. The task involves obvious difficulties. The material is fragmentary and widely scattered, and no trustworthy results could be hoped for unless the investigator had the opportunity of examining practically all the extant material in the original and of procuring facsimiles for purposes of comparison and classification. This extraordinary opportunity has now been put within the writer's grasp by the liberal attitude of the President and Trustees of the Institution in consenting to allow him to undertake the publication of a Corpus of Latin manuscripts prior to 800 A.D., for which the American Council of Learned Societies was able to obtain an adequate grant from the Rockefeller Foundation. The production of the Corpus involves a visit to all of the libraries which possess manuscripts older than 800 A.D.; and the data and photographs thus collected constitute the raw material for investigations which have long been in the writer's mind.

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[1] J. Pelseneer, *Une lettre inédite de Newton* (Isis, 12, 237-54, 1929): *Une opinion inédite de Newton sur l'analyse des anciens à propos de l'Analysis geometrica de Hugo de Omerique* (Isis, 14, 155–165, 1930).

[1] For previous reports see Year Books Nos. 9-28.

It is gradually becoming manifest that before any adequate study of the capital scripts—rustic, uncial, half-uncial—can be attempted, a collection is needed of all the papyri fragments in Latin, since these throw a peculiar light upon the early history of writing. Such a collection is being made. Likewise the influence of Irish and Anglo-Saxon scribes was so important before the Carolingian period that all early examples of "Insular" writing must be studied and photographed. Thus in March a week was spent in Dublin working upon the celebrated Irish books of Kells, Dimma, Mulling, Armagh, etc.; and a fortnight in April in Paris, upon the products of the Anglo-Saxon school of Echternach; also some days in London and in Cambridge upon certain important Insular manuscripts. Finally, during the summer, a week was spent at Schaffhausen studying the celebrated Irish manuscript of Adamnan's *Life of Saint Columba,* written by Dorbbene, probably in Iona, and certainly before the year 713. The result of this work, it is hoped, may soon see the light. During the months of May and June work was continued in Rome in connection with the oldest Latin manuscripts. It is the writer's duty to put on record his profound sense of obligation to the Cardinal Librarian and to the Prefect of the Vatican Library for the privilege they so generously accorded him of access to the stacks, which saved him an enormous amount of time. At the end of May, during a sojourn at Monte Cassino as the Institution's delegate to the Historical Congress, a number of uncial and half-uncial manuscripts were examined and pages selected for photography. In the early part of the year an article on "the unique manuscript of Tacitus' histories" appeared in the centenary volume published by the monks of Monte Cassino. Another article, destined for the Saint Augustine centenary celebration, entitled *The Oldest Manuscripts of Saint Augustine,* has just been seen through the press. During the year, some work was done on ancient marginalia, on the school of Nonantola, and on the *Index of Latin Facsimiles.* The work of checking this Index has just been begun.

The report of W. A. Heidel, Wesleyan University, Middletown, Connecticut, on the *History of Greek Thought,* follows.

During the year I have written a book, tentatively entitled *The Heroic Age of Science,* which deals with Greek science in a way not hitherto attempted. The book does not aim to sketch the history of the sciences, except as it attempts to paint the background against which it must be viewed. Nor does it aim at an exhaustive treatment of any one science. It is rather an effort to illustrate the spirit, ideals and methods of the pioneers in laying the foundations of science in theory and practice. After an introductory chapter devoted to the conception and ideals, successive chapters treat of observation and induction, the use of mechanical analogies in explanation of vital processes, classification and experiment and the experimental method. It is my hope that the book will be of interest and value to students of the history of thought generally and particularly to students of the history of science. The illustrations are drawn from the whole range of Greek science, but especially numerous are those from the medical and other less familiar sources. Negotiations for the publication of the book are in progress.

Meanwhile my assistant, Miss Elsie Spoerl, has been at work on my notes, gathered during fifteen years, on the rôle of Egypt in Greek thought. The subject is large and there are gaps in my materials which I am now engaged in filling. both by studying literary sources not hitherto accessible to me and by visiting Egypt and conferring with leading Egyptologists.

DEPARTMENT OF MERIDIAN ASTROMETRY[1]

BENJAMIN BOSS, DIRECTOR

During the past year the Albany observational catalogue of star positions has been completed and the work on the General Catalogue has progressed favorably. In addition very interesting relationships have been found between astronomical and geophysical observations which indicate that the Earth is pulsing through the agency of incoming radiation from the Sun, governed by the Earth's magnetic field. Speculative hypotheses have been advanced to account for the crustal formations of the Earth and for cosmic evolution.

THE ALBANY CATALOGUE

The last steps in the preparation of the Albany Catalogue of star positions have been completed and the manuscript is ready for publication. This catalogue supplements the San Luis Catalogue, published in 1928, the latter containing the positions of southern stars, while the former lists the positions of the northern stars. The observations contained in these two catalogues form a part of the general program of the Department, being designed to furnish a modern homogeneous system, from pole to pole, of the positions of the stars which will be included in the General Catalogue. The publication of the Albany Catalogue will mark the passing of another milestone in the general program.

THE GENERAL CATALOGUE

During the past year satisfactory progress has been made in various steps leading to the formation of the General Catalogue. Systematic corrections and weights have been determined for all the catalogues which will be employed in deriving the standard positions and motions, with the exception of three received since January 1, 1930. With the same exception all the observations have been entered in the card catalogue of positions. The comparison of the observed positions with provisional ephemerides is complete for the miscellaneous stars, both north and south, and has been begun for the stars contained in the Preliminary General Catalogue. The application of systematic corrections to reduce the observations to a homogeneous system is nearly completed for the northern miscellaneous stars. Ephemerides have been prepared for northern stars, mainly north of 60° declination, which were added to the original observing list because of indicated large proper-motion. Trigonometric expansions have been made for all stars not in the Preliminary General Catalogue whose declinations lie between 80° and the pole. Also many revisions have been made for double stars and stars where the assumed proper-motions were too much in error.

MISCELLANEOUS INVESTIGATIONS

RELATIONS BETWEEN ASTRONOMICAL AND GEOPHYSICAL OBSERVATIONS AND THEIR INTERPRETATION

The indication of changes in the rate of rotation of the Earth over periods of years, pointed out by E. W. Brown and W. de Sitter, suggested the possibility that this effect might play some part in creating some of the errors found in observed star positions. But until the forces producing the irregular rotation of the Earth are understood, no satisfactory conclusions as to resultant effects can be derived. Consequently an attempt has been made to discover what lies back of the irregular rotation of the Earth. This has necessitated the compilation of geophysical and astronomical observations with a view to establishing relationships between them. Piece by piece these facts have been fitted together leading to interesting conclusions. These conclusions, in turn, have suggested speculative hypotheses of the crustal conformations of the Earth and of cosmic evolution.

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[1] Address: Dudley Observatory, Albany, New York.

In the first place evidence has been found to indicate that penetrating radiation emanating from the Sun is responsible for the maintenance of the electric charge of the Earth, while the magnetic field of the Earth regulates the varying amount of the charge during the day. In turn, the electric charge, which is varying during the day, the year, and from year to year, is producing a daily, an annual and longer period pulsations of the Earth. These conclusions have been derived through relationships between such apparently unrelated subjects as the motions of the Moon, Sun and planets, the electric charge upon the Earth, magnetic data and earthquake phenomena.

It has been shown, for instance, that in their daily distributions the electric charge on the Earth, the frequency of earthquakes, magnetic oscillations in the polar regions and other phenomena are all related to the position of the Sun with regard to the magnetic field of the Earth. And in the case of annual and secular changes the motion of the Moon corroborates the other data.

SPECULATIVE HYPOTHESIS OF CRUSTAL FORMATIONS

The pulsation of the Earth suggests that it is this which is largely responsible for the crustal formations on the Earth. With the caution that this part of the investigation is speculative and therefore not to be taken as fact, the following hypothesis is offered.

The denser portions of the Earth's crust have sunk into the layer of less rigid material under the outer crust as a result of the constant pulsations of the Earth, crowding out the underlying material. The boundaries of these areas bear the brunt of the crustal motion. They fold up, sometimes cracking and slipping over the adjoining regions—the start of mountain ranges. But some of the crowding substratum passes onward and gradually lifts up the growing continent, the uplift being progressively smaller as you pass from seaboard toward the interior. This in its simplest form gives the concave form of North America. Continued pressure in the border regions lifts up the mountains on the one hand and creates the off-shore deeps on the other hand. As a result of the deeps it becomes more difficult for the substratum material to force its way toward the continents. Consequently the crust under the oceans tends to develop a convex form.

The great strains in the crust in the regions bordering the seas prepare the way for earthquakes and the pulsations of the Earth act as the trigger effect to set them going. Also in these regions large fissures are opened up through which water is admitted to the hot regions lower down. The water becomes vaporized and, when this superheated vapor exerts too great a pressure, it seeks an outlet through the weakest part of the crust, exploding and causing a volcano.

At the present time the principal crustal activity is around the borders of the Pacific Ocean and throughout a strip extending from the Mediterranean through southern Asia. In these regions are found all the young mountains. In time past, however, the activity extended to the Atlantic also. While this region has been comparatively quiescent for a long time, the fact that gravity experiments indicate for the crust underlying the Atlantic a density considerably in excess of that of the bordering continental areas points to the possibility of further sinking with consequent increased activity along its shores.

Speculative Hypothesis of Cosmic Evolution

The second speculation deals with the cosmos. The apparent pulsing of many of the stars may be caused in the same way as the Earth pulsations. The latter call for a magnetic field with poles displaced with respect to the poles of rotation and a directive stream of radiation. The Sun, a typical star, possesses a magnetic field and displacements of its poles with respect to the poles of rotation. Presumably other stars exhibit the same phenomenon. All that is required to cause pulsation is a directive stream of radiation. The stars are sending out a tremendous amount of radiation. I suppose that the motion of this radiation is governed by a magnetic field of the Milky Way. The poles of such a field will be located near the poles of rotation of the Milky Way passing through the center in Sagittarius. As a matter of fact recent work has shown that there is greater obscuration as the Milky Way is approached, possible evidence of instreaming radiation. Also there is a great dark obscuring cloud splitting the Milky Way from Cygnus to Centaurus with its center in Sagittarius. If an incoming streaming radiation is causing the obscuration and the cloud, it furnishes the last element needed for star pulsing. The pulsing stars are located near the plane of the Milky Way where they would be subject to the streaming influence.

If the recent announcement by Milne regarding the constitution of a star is correct, the foregoing leads to a cycle of evolution. The Milky Way, as we have recently found, is rotating. As a result of the processes to be described, the cosmic clouds bear a predominant negative electric charge. Thus a magnetic field is generated. The stars evolving from the cosmic material also carry a residual negative charge. These stars, in revolution about the center of the galaxy, possess magnetic fields also by virtue of their rotations upon their axes. As a result, there is added to the revolution of the star around the center of the Milky Way a magnetic repulsion which tends to drive it outward, thus producing the spiral formation of island universes. But if the typical star is formed as Milne has announced, the stars are shedding a greater amount of negative charge than positive. Thus in the course of time a star being driven outward from the center of the Milky Way will acquire a predominant positive charge, its magnetic field will be reversed and it begins to be drawn in toward the center again, a phenomenon which I discovered several years ago.

As consequences of the proposed scheme of evolution we can account for novæ, the "white dwarf" stars, stars of great brilliancy, comets and meteors. In fact, it appears to satisfy all the observational data better than any hypothesis heretofore advanced. But it is a speculation and therefore can only serve in directing attention to the advisability of introducing electromagnetic effects in accounting for the evolution of the cosmos.

It is a great pleasure to acknowledge the helpfulness of Acting Director Fleming and his associates in the Department of Terrestrial Magnetism in assisting me to gather requisite data. I am also greatly indebted to Commander N. H. Heck and to the Coast and Geodetic Survey for the aid they have so pleasantly granted.

GALACTIC ROTATION

Continuing his studies of stellar motions, Wilson has shown that the motions of the stars whose space motions have been determined are so distributed that they may be fairly well represented on the theory that the stellar system is rotating about a center in galactic longitude 329°, at a rate represented by the rotational coefficients, $A = +0.015$, $B = -0.016$ km./sec./parsec. The angular rate of rotation in the neighborhood of the Sun is $0\overset{''}{.}0065$ per year and the period of rotation, therefore, is 200,000,000 years. He finds the distance of the Sun from the center of the galaxy to be 8800 parsecs.

POSITIONS AND PROPER-MOTIONS

At the request of Dr. J. S. Plaskett, Director of the Dominion Astrophysical Observatory, Wilson has determined the preliminary proper-motions of 298 Class-B stars for use in Plaskett's studies of the motions of these stars. He has also determined the positions of 96 occultation stars for Professor E. W. Brown, of Yale University.

STELLAR WAVE LENGTHS

Albrecht has completed his determinations of wave-lengths and identifications of the spectrum lines of Gamma Geminorum The manuscript is now in the hands of the printer. He has begun a similar study for the standard velocity star Procyon, of spectral class F5. Several hundred lines have been measured on two spectrograms of this star.

Albrecht's measures of radial velocity and of wave-lengths of spectrum lines, based upon spectrograms taken with three-prism dispersion at the Yerkes Observatory, have been put into manuscript The spectrograms were distributed among six stars as follows: γ Corvi, 5; β Canis Maj., 3; γ Pegasi, 2; ζ Draconis, 2; β Orionis, 4; ι Hercules, 4.

STAFF

There have been no major changes in the staff during the year. In the computing division Mrs. Virginia J. Weidmann was appointed a computer on March 1. Miss Marie Lange resigned on April 15. Mrs. Thora L. Lawson was appointed on May 1 to fill the vacancy caused by the resignation of Miss Lange. Mrs. Lawson resigned on June 15 and Miss Evelyn Clifford was appointed to fill the vacancy. Six part-time workers have also been employed during the year.

MOUNT WILSON OBSERVATORY

George E Hale, Honorary Director
Walter S. Adams, Director
Frederick H. Seares, Assistant Director

The work of the Observatory during the year has been marked by several notable developments in its research problems, and one important addition has been made to its instrumental equipment. Preliminary tests of the 50-foot interferometer were obtained during the spring months and seem to leave little doubt of the successful performance of this unique and powerful instrument. Fringes have been observed without difficulty at nearly the full separation of the outer mirrors, and the results obtained are in good accord with those to be expected from an extension of the values measured with the 20-foot interferometer on the 100-inch telescope.

The continuation of observational work on the spectra of extra-galactic nebulæ has led to the discovery of red-shifts or apparent velocities of recession much greater than any hitherto observed, and has added strong evidence for the existence of the relationship between distance and apparent velocity derived by Dr. Hubble. This field of research gives us the only means at present at our command for investigating the properties of space and of radiation through space up to very great distances, and has formed the basis of several important theoretical investigations of this most fundamental problem. The latest observations by Mr. Humason on a cluster of faint nebulæ in Ursa Major have shown red-shifts of about 165 angstrom units, or +11,500 km./sec. in terms of radial velocity. The distance of this cluster is of the order of 75,000,000 light-years.

The Mount Wilson Catalogue of Photographic Magnitudes in Selected Areas 1–139 by Seares, Kapteyn and van Rhijn has been printed and distributed during the year by the Carnegie Institution of Washington. This catalogue, containing photographic magnitudes of 67,941 individual stars, represents the completion of a great investigation which owed its inception to the far-reaching plans of Professor Kapteyn and was brought to a successful completion by Dr. Seares and his associates. The description of the development and application of new methods of photographic photometry with reflecting telescopes, the intercomparison of results and the study of sources of error, as well as the great wealth of observational data, especially for faint stars, contained within this volume, will make it of fundamental value to those engaged in studies of the brightness of stars and problems of stellar distribution.

The material for an extensive monograph on the magnetic fields and polarities of sun-spots by Dr. Hale and Dr. Nicholson has been collected and is now nearly ready for publication This will contain about 1300 reproductions from wax engravings of the drawings made during the years 1917-1924 with the 150-foot tower telescope. They will show the positions and forms of all sun-spots, with the observed directions of polarity and the values of the intensity of the magnetic field in gaussian units. An introduction will describe the methods used in the observations, and will discuss the important question of the reversal of polarity in the double sun-spot cycle. A large amount of data in a field in which observations are at present carried on only at Mount Wilson will thus become available to investigators in solar physics and related subjects.

The Observatory has contributed throughout the year in many ways to the progress of the plans for the 200-inch telescope. Dr. Hale has devoted much of his time to the more general questions involved in the project, Dr. Anderson has continued as Executive Officer in immediate charge of the plans, and Dr. Pease and Dr. Smith have each given a portion of their time to the work. The investigation of sites has utilized to advantage the wide experience and knowledge of observing conditions of Mr. Ellerman and Mr. Humason, and the Advisory Committee has assisted in the consideration of plans for the telescope and accessory buildings. Several of the 22-inch fused silica disks made by the General Electric Company in the course of its experimental work on the methods to be employed in the manufacture of the 200-inch disk and the auxiliary mirrors have been figured in our optical shop and tested under a wide variety of temperature conditions with most interesting results.

Two immediate consequences of the close association of the Observatory in the plans for the 200-inch telescope and the development of its accessory instruments have been the design and successful operation of the correcting lens planned by Dr. Ross for extending the field at the primary focus of reflecting telescopes, and the extraordinarily efficient lens of focal ratio 0.6 designed and constructed by Dr. Rayton of the Bausch and Lomb Optical Company. The funds for both these important accessories were provided from the appropriations available for the 200-inch telescope at the California Institute of Technology. Even the preliminary tests of the correcting lens showed so great a gain in field of sharp definition as to make it probable that its further development will partially revolutionize the work of the reflecting telescope, while the remarkable light-gathering power of the short-focus camera lens has made it possible to secure spectroscopic results on distant nebulæ and faint stars which were previously quite out of reach of observation.

The preparations necessary for Dr. Michelson's measurement of the velocity of light by the method of a rotating mirror operating through a pipe line exhausted of air have been carried on during the year and are nearly completed. The work has been made possible through the grant of funds by the Rockefeller Foundation and the Carnegie Corporation of New York. One mile of 36-inch corrugated steel pipe has been purchased and set up on a strip of land belonging to the Irvine Ranch Company, which through Mr. James Irvine jr. has cooperated most generously in the plan. The design and installation of air-tight connections at the junctions of the sections of pipe and of the large steel cylinders housing the mirrors at the ends of the line have been completed, and the entire optical system with slow-motion controls has been placed in position. During the winter a section of pipe 1140 feet long was exhausted to a pressure of about 15 mm. and the performance of the optical system was tested thoroughly. Recent trials on the full length of one mile have shown that a pressure of 10 mm. can probably be maintained without difficulty, and that at such a pressure ample light will be available in the image after reflection over the 10-mile path which Dr. Michelson is planning to use in his measurements.

The total solar eclipse of April 28, 1930, was observed by a small party from the Observatory at a station near Honey Lake, California. The very brief duration of the eclipse, about 1.3 seconds, precluded some types of observations, and the program was confined to certain definite spectroscopic and photometric problems. Light clouds covered the sun at the total phase and prevented securing photometric results of value. The spectroscopic observations, however, were successful to a quite unexpected degree and will provide material for important studies of the solar atmosphere.

STAFF

Dr. George E. Hale, Honorary Director of the Observatory, has continued his observations of solar phenomena with the spectrohelioscope at the Solar Laboratory, and has devoted much time to problems relating to the 200-inch telescope. Dr. Walter S. Adams, Director, has carried on the administrative work of the Observatory and has been engaged in research in stellar spectroscopy. Dr. Frederick H. Seares, Assistant Director, has shared in the administrative work and has continued his photometric and statistical investigations. Dr. Seares has also edited the publications of the Observatory.

Dr. John A. Anderson has given much of his time to the consideration of the many questions involved in the design and location of the 200-inch telescope and of the buildings and equipment essential to its construction and operation. He has continued in the physical laboratory some of his studies on high-tension discharges and certain optical problems. Dr. Arthur S. King, Superintendent of the Physical Laboratory, has extended his researches on the spectra of the rare earths and has given special attention to the spectrum of the isotope of carbon. Dr. Charles E. St. John has been engaged in microphotometric measurements of the intensities and contours of the lines of multiplets in the solar spectrum. Dr. St. John retired from the staff of the Observatory on January 1 and was appointed Research Associate from that date. Dr. Edwin Hubble has developed his methods for obtaining the distribution of luminosity in extra-galactic elliptic nebulæ, and has derived further results bearing on the relationship of red-shift to distance among the farthest nebulæ observed. Dr. Paul W. Merrill has continued with interesting results his investigations of the spectra of early-type stars showing emission lines. Mr. Harold D. Babcock has extended his work on the infra-red spectrum of the sun, and has investigated further the molecular spectrum of oxygen. In addition to other laboratory researches he has given much time to the supervision of the ruling machine and a study of the characteristics of the diffraction gratings which have been made with it. Professor Alfred H. Joy, Secretary of the Observatory, has continued spectroscopic observations of variable stars and has completed orbits for several stars with known photometric data. Dr. Seth B. Nicholson has remained in general charge of the solar observations and has devoted much time to polarity measurements in sun-spots and to the compilation of material for the forthcoming publication by Dr. Hale and himself. Dr. Nicholson after an extended search found on photographs taken in 1919 the trans-Neptunian planet discovered at the Lowell Observatory, and with the assistance of Mr. Mayall derived a satisfactory orbit. Dr. Francis G. Pease has given a portion of his time to work connected with the 200-inch telescope. He has also carried on observations with the 20-foot interferometer and the nebular spectrograph on Mount Wilson, and has made the preliminary tests of the 50-foot interferometer and of the optical system for the measurement of the velocity of light by Dr. Michelson. Dr. Adriaan van Maanen has continued his photographic measurements of the proper motions and parallaxes of stars. Dr. Edison Pettit has made further observations of the ultra-violet radiation of the sun and sky, and in collaboration with Dr. Nicholson has investigated the spectral energy of sun-spots and the radiation and temperature of the moon and Mars. Dr. Roscoe F. Sanford has studied the variations in radial velocity of numerous spectroscopic binaries and has completed and published several orbits. Dr. Gustaf Strömberg has assisted in the stellar spectroscopic observations and has developed and applied methods for deriving the distribution in absolute magnitude of stars of types K and M from their peculiar and parallactic motions. Dr. Theodore Dunham jr. has been engaged in studies of methods of standardizing stellar spectrograms and determining line-contours, and has applied his results to photographs taken with the high-dispersion coudé spectrograph. Mr. Milton Humason has devoted most of his time to the difficult work of photographing the spectra of faint extra-galactic nebulæ and has obtained results of great interest. Dr. Sinclair Smith has investigated further the theory and construction of radiometers and has commenced measurements of the spectral energy distribution of stars with the 60-inch reflector. Dr. Smith has also given a part of his time to investigations at the Seismological Laboratory and to certain problems connected with the 200-inch telescope. Mr. Ferdinand Ellerman has continued his solar observations and has carried on much of the general photographic work of the Observatory. Mr. Joseph Hickox has been the regular solar observer on Mount Wilson and has assisted in the testing of plates and other photographic work.

In the Computing Division Miss Louise Ware has devoted all her time to the study of solar and stellar spectra with the large registering microphotometer. Miss Elizabeth Sternberg has studied the numbers and areas of sun-spots and flocculi as measures of the solar activity and has compiled the records of sun-spot activity and magnetic polarity. Much of the work of preparing the descriptive material for the publication on sun-spot polarities was carried on by Mrs. Lewis H. Humason, who spent three months at the Observatory. Mr. Edward F. Adams has measured and reduced spectrograms of the center and edge of the sun. Miss Mary C. Joyner has assisted Dr. Seares in the reduction of the photovisual magnitudes of the stars in many of the Selected Areas. The burdensome proof-reading of the *Mount Wilson Catalogue of Selected Areas*, involving a comparison of both first and second proofs with the manuscript copy, was completed by Miss

Joyner with the aid of Miss Alice S. Beach. Miss Myrtle L. Richmond has measured and reduced the curve tracings obtained in the course of radiometric observations of sun-spots, the moon and planets. Mrs. Hannah M. Marsh resigned her position on January 10, and since that time Mr. V. M. Sokoloff has assisted Dr. van Maanen in his determinations of stellar parallax and proper motion. Miss Elizabeth MacCormack has been engaged in measurements of radial velocity and computations relating to stellar motions. Miss Cora G. Burwell has continued her work with Dr. Merrill on the spectra of stars showing emission lines. Mr. Nicholas Mayall has shared in the spectroscopic and direct photographic observations on Mount Wilson and has made measurements of radial velocity from the stellar spectrograms. Mr. William H Christie has also taken part in the observing and has been investigating certain stars of variable radial velocity. Miss Ada M Brayton has divided her time between computations of the absolute magnitudes of stars and the measurement and reduction of laboratory spectra. Mr. Wendell P. Hoge has assisted Mr. Babcock in the physical laboratory and has measured many of the spectrograms. Miss Elizabeth Connor has continued in charge of the library and has aided in the editorial work.

Dr. A. A. Michelson, Research Associate of the Institution, spent the months of June, July and August 1929 in Pasadena and was engaged in making preparations for his measurement of the velocity of light through a pipe-line exhausted of air. He returned to Pasadena in June 1930 and will remain to carry on his observations Dr. Henry Norris Russell, Research Associate, has been spending the year in Europe and so has not visited the Observatory in accordance with his usual custom. Sir James Jeans was in the eastern United States during the early months of the present year but was prevented by illness from coming to Pasadena as he had planned.

Dr. Fred E. Wright, of the Geophysical Laboratory of the Carnegie Institution and Chairman of the Committee on the Study of the Surface Features of the Moon, was in Pasadena during September and October 1929. He carried on lunar observations on Mount Wilson and gave some time to the design of apparatus for constructing a large-scale photographic map of the moon. A meeting of the Committee was held on Mount Wilson during his visit. Dr. B. W. Sitterly, Professor of Astronomy at Wesleyan University, has been in Pasadena since December 1929. He has carried on photometric observations on Mount Wilson and in collaboration with Dr. Seares has been determining the photographic and photovisual magnitudes of the comparison stars in the southern fields within which the asteroid Eros will appear during the coming opposition. Dr. C. D. Shane, Professor of Astronomy at the University of California, has continued during the present summer his observations of the intensities of solar spectrum lines by the interference method he has developed. Dr. John C. Duncan, Director of the Whitin Observatory of Wellesley College, carried on direct photographic observations during the summer months of 1929. Dr. Frank E. Ross, of the Yerkes Observatory, was in Pasadena during August and September 1929. Although he was concerned mainly with questions relating to the 200-inch telescope, his advice and experience proved of great value to the Observatory in connection with many optical and instrumental problems. Dr. Otto Struve, also of the Yerkes Observatory, came in June 1930 and has been using the coudé spectrograph and the 100-inch reflector for observations of B-type stars with high dispersion. Dr. Knut Lundmark, Director of the Observatory of Lund, spent several months in Pasadena. He was engaged principally in the compilation of his large catalogue of nebulæ and utilized for this work many of the negatives in the Observatory files. Dr. Leon Hufnagel, Fellow of the International Education Board, carried on observations during the autumn months on the colors of faint stars in certain areas of the sky. Mr. R. v. d. R. Woolley, Fellow on the Commonwealth Fund, has spent most of the year in Pasadena, arriving in September 1929. He has devoted most of his time to observational work on the intensities and contours of selected solar spectrum lines and theoretical investigations of the atomic transitions involved. Dr. Frank S. Hogg, of the Harvard College Observatory, has spent a few weeks of the present summer in Pasadena and has made observations of the distribution of intensity across globular star clusters with the 60-inch reflector.

Many of the members of the staff have taken an active part in the scientific meetings held throughout the country, including those of the National Academy of Sciences, the American Association for the Advancement of Science, the Astronomical Society of the Pacific, and the American Physical Society. Babcock, Merrill and St. John have visited numerous observatories and laboratories of universities and industrial organizations during the year, and Adams and Babcock attended the annual meeting of the Carnegie Institution at Washington in December.

In accordance with a practice established several years ago, members of the staff gave two series of public astronomical and physical lectures in Pasadena and Los Angeles during the winter months. These lectures are maintained jointly by the Carnegie Institution and the Astronomical Society of the Pacific and have met with cordial support and appreciation. Other lectures and addresses of a less formal character, too numerous to list in detail, have been given throughout the year.

SUMMARY OF THE YEAR'S WORK

Sun-spot activity showed a distinct falling off in 1929 as compared with the two preceding years, although there was a marked revival in December. Spectroheliograms were obtained on 312 days between July 1, 1929, and June 30, 1930, and records of the polarity and strength of magnetic field on 324 days during the calendar year 1929. Among the 346 spot groups examined, 271 were found to be regular in the sign of their magnetic fields, 8 irregular, and 67 could not be classified. The solar observers were Ellerman, Hickox, Nicholson and Richardson.

Work with the spectrohelioscope has been continued by Hale at the Solar Laboratory and by the observers on Mount Wilson. In addition to publishing some of his extensive observations with this instrument, Hale has organized further the plan for cooperative investigations with the spectrohelioscope, with the result that 15 observatories and institutions throughout the world are planning to take part in the work.

Miss Moore and Richardson have undertaken detailed studies of the intensities and identifications of lines and bands in the sun-spot spectrum and of the atomic and molecular processes involved in their behavior. Pettit and Nicholson have compared the energy radiation of sun-spots with that of the photosphere and find a nearly linear increase from 0.21 at $\lambda\,0.3\,\mu$, to 0.81 at $\lambda\,1.71\,\mu$, after which it becomes nearly constant. The ratio of total energy radiation of spot to photosphere is 0.477, the fall being nearly continuous from photosphere to umbra. These results are all for spots of medium size. A temperature of 4800° K for the umbra of spots, and of about 5950° for the center of the sun, results from these measures.

St. John has used his results on line-shifts to prove that all lines in a given multiplet in the solar spectrum, regardless of intensity, have equal displacements toward the red. He has also shown that the excitation potentials at which various atomic transitions occur govern in large degree the possibility of the presence of lines in the solar spectrum, their intensities, and the relative heights to which they rise in the sun's atmosphere.

Other investigations relating to the solar spectrum have included Babcock's continuation of his work in the infra-red, where his measurements now extend to λ11,634; St. John's measures of the solar rotation and limb-center displacements; and a statistical study by Babcock of the relative numbers of lines of different intensities as listed in Rowland's table. Microphotometric measurements of the contours and intensities of selected multiplets and other groups of lines are in progress by Dr. Shane, St. John and Mr. Woolley.

The monthly average of the ratio of the solar energy at $\lambda\,0.32\,\mu$ to that at $\lambda\,0.5\,\mu$ reached the very high level of 1.52 in January 1930. The lowest value during the year was 1.15 in April 1930. These results are due to Pettit, who has also investigated the ultra-violet limit of the sky spectrum with two crossed monochromators. The limit so far observed is $\lambda\,0.293\,\mu$.

The total solar eclipse of April 28, 1930, was observed by a small expedition at Honey Lake, California. Thin clouds prevented photometric observations of value, but some of the direct photographs and spectroscopic results are of interest. More than 2000 bright lines are shown on a film taken by Dunham with a concave-grating spectrograph.

Direct photographs of the moon, including two series of motion-picture negatives, have been made by Pease. Dr. F. E. Wright has developed a method for constructing a large-scale map of the moon from the Mount Wilson photographs, and has designed a small quartz spectrograph with a Wollaston prism for studying the nature of lunar materials through the polarization and selective reflection of the light received from the moon.

Pettit and Nicholson find from radiometric measures that the distribution of energy about a surface of unit area on the moon does not follow the cosine law. The computation of the temperature of the sub-solar point by different methods leads them to conclude that the transmission of the earth's atmosphere between 8 μ and 14 μ is about 19 per cent greater than has generally been supposed. This would reduce somewhat the temperatures of the moon and planets as derived from radiation measures. The final value for the temperature of the sub-solar point is found to be 374° K and that of the dark side of the moon less than 120° K.

A similar reduction of the observations of Mars made with a thermocouple in 1924 gives for the temperature of the sub-solar point at perihelion 294° K. Those of 1926 give 297° K. The great eccentricity of the orbit would make the temperature 27° lower at aphelion.

The announcement of the discovery of the trans-Neptunian planet Pluto at the Lowell Observatory led Nicholson to repeat a search for images of the planet on photographs taken in 1919 with the 10-inch photographic telescope. Images were found on four negatives of a rich region in the Milky Way, and these positions, combined with more recent observations, have enabled Nicholson and Mayall to compute a satisfactory orbit.

Most of the direct photographs of nebulæ made during the year have been by Hubble, with some assistance from Mayall. Dr. Duncan has obtained several negatives, including one with an exposure time of nine hours on the northern part of the nebulous wreath in Cygnus which shows several new filaments. A plate of Nova Aquilæ 1918, taken by Dr. Duncan on June 30, 1930, shows that the nebulous envelope, now 23″ in diameter, has been growing fainter and enlarging at a uniform rate. Hubble has counted about 10,000 nebulæ on his photographs, and finds a very irregular zone of avoidance along the Milky Way, with a fairly uniform distribution in higher galactic latitudes. In these latitudes the numbers of nebulæ increase with the exposure times as though they were distributed in space with approximate uniformity.

Hubble has completed and published an investigation of the distribution of luminosity along the axes of 15 elliptical nebulæ, using a recording microphotometer for measuring the photographic images. The curve representing the three-dimensional distribution of luminosity exhibits an interesting similarity to that which expresses the distribution of density in an isothermal gas sphere.

The need for accurate photographic and photovisual magnitudes in nearly all investigations dealing with extra-galactic nebulæ is so great that Hubble has commenced a study of the photometric problems involved, using the method of extra-focal images. A sequence of nebulæ in the Virgo cluster has been selected for purposes of intercomparison. Provisional results on color indices suggest a color excess in low latitudes which may depend on latitude and not on distance. Such a result would have an important bearing on the question of absorption and scattering of light within the galactic system.

Humason has secured during the year spectroscopic observations on 15 extra-galactic nebulæ, more than half of which are members of five clusters. The remainder are isolated nebulæ with apparent radial velocities ranging from +750 to +4100 km./sec. A very faint nebula in the Ursa Major cluster, observed with a camera of focal ratio 0.6 and an exposure of 45 hours, shows the largest red-shift so far found for any object, amounting in terms of radial velocity to +11,500 km./sec. Hubble had previously assigned to this nebula a distance of 75,000,000 light-years.

The new results for the velocities of extra-galactic nebulæ extend the observed range in distance about twelvefold, and add strong confirmation to the velocity-distance relationship derived by Hubble. This correlation is closely linear and amounts to about 500 km./sec. per 1,000,000 parsecs. It depends upon the velocities of 58 isolated nebulæ and 22 nebulæ in five clusters, for which distances have been determined by various methods. Except for a single nebula in the Coma cluster, which may be explained as a field nebula seen in projection, the correlation between velocity and distance is excellent for all of the objects. The distances in parsecs of three clusters of nebulæ for which radial velocities have been determined recently are:

Pegasus 8×10^6; Perseus 10.5×10^6; Ursa Major 24×10^6

In continuation of his measurement of trigonometric parallaxes, van Maanen has derived values for 17 fields. Eight of these are dwarfs with absolute magnitudes of +10.0 or fainter. The absolute parallax of B.D. +43°4305 is +0″.213, which places it among the nearest 25 stars known

Van Maanen has measured the proper motions of 133 stars in the open cluster N.G.C. 2264 from plates taken 11 years apart, and has completed determinations for six planetary nebulæ. Their motions range from 0″.001 to 0″.010, corresponding to a mean parallax of about 0″.001. Nine photographs of the stellar nucleus of the spiral nebula N.G.C. 4051 have been measured and give the proper motions, $\mu\alpha = -0''.003 \pm 0''.0008$, $\mu\delta = +0''.015 \pm 0''.0011$. It appears difficult to account for the large motion in declination on the basis of magnitude or other errors. The spectrum, however, is of the planetary nebula type.

The *Mount Wilson Catalogue of Photographic Magnitudes in Selected Areas 1–139* by Seares, Kapteyn and van Rhijn was completed during the year and the volume has appeared in print.

Seares and Miss Joyner have derived photovisual magnitudes to the limit of about 15.5 for the stars in zones +45° and +30° of the Selected Areas. The scale is established partly by diaphragm exposures and partly by polar comparisons, and then strengthened by averaging the results for three successive areas. A somewhat analogous investigation not yet completed is the determination by Seares and Dr. Sitterly of the photographic and photovisual magnitudes of the comparison stars for Eros south of the equator.

The adjustment of the 50-foot interferometer and tests of its optical performance are being made by Pease with satisfactory results. Fringes have been observed to a distance of 34 feet, and the mechanical operation of the instrument is in general excellent.

About 1400 stellar spectrograms have been obtained during the year in the course of a wide variety of investigations. Especial attention has been given to the study of the radial velocities and spectral changes of many variable stars and spectroscopic binaries, stars with emission lines, and bright stars photographed with high dispersion.

A catalogue of the radial velocities of 741 stars has been published by Adams, Joy, Sanford and Strömberg, and the velocities of several hundred other stars in the Selected Areas, Boss's *Catalogue*, and other observing lists, have been measured on two or more spectrograms. Sanford has nearly completed his program of work on N-type stars, having determined between 60 and 70 radial velocities.

Joy has given special attention to certain eclipsing variables, including X Trianguli, RT Sculptoris, W Ursæ Minoris, RT Lacertæ, RS Canum Venaticorum and U Sagittæ. In the case of several of these stars the combination of the spectroscopic and photometric observations has made it possible to derive absolute masses and dimensions for the systems. TT Aurigæ, in which both components are of type B3, shows both stellar and interstellar H and K lines. The brighter component of U Sagittæ has the spectral type B9, and the fainter but larger component the type G2. Observations made during the total eclipse of 100 minutes have been sufficient to determine the slope of the velocity curve, and hence to give the relative masses of the two stars.

Sanford has determined the forms of the velocity curves of the Cepheid variables U Aquilæ and DT Cygni, and has nearly completed the orbits of the spectroscopic binaries Boss 5575 and Boss 5846. He finds that the radial velocity observations of the M-type variable R Lyræ obtained at different observatories point to an oscillation in the star's mean period of 43.48 days. Sanford has also been studying the stars U Monocerotis, AC Herculis and V Ursæ Minoris, with periods intermediate between those of the Cepheids and the long-period variables, and several other stars, including α Orionis and ζ Geminorum, for which he has used spectrograms of high dispersion.

The approximate velocity curves of 10 Cepheids and short-period variables have been derived by Joy, and the periods of several spectroscopic binaries by Christie. Observations of ε Aurigæ with the coudé spectrograph by Adams and Sanford showed the presence of double lines in November 1929 and February 1930, and give added importance to the study of this interesting star.

Merrill and Miss Burwell have investigated the displacements and changes in relative intensity of the bright lines in the spectra of Me and Se stars throughout the light-cycle. In Me stars the ratio $H\gamma : H\delta$ is found to rise rapidly from 0.1 to 0.5 shortly before maximum, to remain nearly constant for a time, and then to rise still more rapidly to 2.5 at about halfway between maximum and minimum. The apparent velocities from the bright lines show algebraically decreasing values at and shortly after light-maximum, and a flat minimum 30 to 80 days following this phase. Several bright lines have been newly identified, including forbidden iron lines and an ultra-violet magnesium triplet. The existence of titanium oxide above the level at which the bright lines are produced is suggested as a hypothesis to explain the abnormally low intensities of $H\alpha$, $H\beta$ and $H\gamma$ as compared with $H\delta$.

Additional stellar spectroscopic investigations have included further studies of bright-line B stars by Merrill and Miss Burwell; the discovery and examination of the structure of bright H and K lines in giant stars by Adams and Joy; the attempt by Adams and Sanford to correlate relative line-displacements with excitation potential in the spectra of certain stars; and the essential completion of the classification of the spectra of faint stars in the Selected Areas by Humason.

Dunham has developed a special sensitometer for impressing monochromatic standards on stellar and solar spectrograms, and has applied the method successfully to the photographs taken with the coudé spectrograph. He has also studied various types of recording devices for the microphotometer, and the possibility of utilizing a short-period galvanometer with an amplifier in connection with this instrument.

Determinations of absolute magnitude and parallax by the spectroscopic method have been continued by Adams and Humason. The revision of the reduction tables for dwarf stars to provide for the inclusion of additional lines has been completed, and the absolute magnitudes of about 1500 stars have been computed. A comparison of the results for 580 stars with those derived from the trigonometric parallaxes of Schlesinger's *Catalogue* gives a mean difference of −0.03 magnitude. The revision of the reduction tables for giant stars of types A to K5 is also complete, and the computation of the absolute magnitudes is well advanced.

Strömberg has developed a method for calculating the frequency-distribution of absolute magnitudes among stars from their angular peculiar motions and radial velocities, and has applied it to those of types K and M of apparent magnitude 6.0 or brighter Among stars of types K0 to K2 he finds four frequency-maxima, at absolute magnitudes −1.8, +0.2, +2.9 and +6.7; among stars of types K3 to K9, three maxima, at −2.4, −0.1, and between +4 and +9; among M-type stars, only two maxima, since dwarf stars are not included, at −1.6 and +0.1. In order to strengthen the determination for the M stars, which depends on somewhat scanty material, he has developed an analogous method which utilizes the parallactic motions. This gives two maxima, at absolute magnitudes −4.5 and −0.2.

In the physical laboratory King has completed the classification according to ionization and temperature of 2268 lines between λ 3850 and λ 4700 in the spectra of the rare-earth elements, europium, gadolinium, terbium, dysprosium and holmium. The introduction of cæsium into the electric furnace has been used successfully to identify the enhanced lines, which are extinguished under these conditions. The wave-lengths of about 800 new lines have been measured, and many probable identifications have been made with faint solar lines. A survey of the rich spectra of neodymium and samarium shows the presence of 4500 lines between λ 2800 and λ 7000 available for temperature classification. Of this work a part has already been completed. An interesting feature of these spectra is the probable occurrence of the lines of illinium, an element intermediate in the atomic sequence, regarding the spectrum of which little is as yet known.

King has previously called attention to the fact that a large proportion of the lines of the rare-earth elements of odd atomic number show hyperfine structure, a feature ascribed to nuclear spin in modern spectroscopic theory. Among the elements studied recently by King europium, terbium, and especially holmium show this behavior prominently. Similar structure in the case of praseodymium was investigated by Professor Gibbs and Dr. Gartlein of Cornell University in the summer of 1929 with the large spectroscopes in the Pasadena laboratory and on Mount Wilson. In cooperation with Dr. Meggers of the Bureau of Standards, King is measuring the wave-lengths of the lines in the spectrum of columbium, another element in which hyperfine structure is conspicuous.

Reference was made in last year's report to the discovery by Dr. Birge and King of a carbon isotope of mass 13. Further work by King with the electric furnace has resulted in spectrograms of better quality on which 15 component lines of the band at λ 4744.5 due to the $C^{13}C^{12}$ molecule have been measured, and several additional bands involving C^{13} have been detected. Dr. Birge's calculations show that the spacing of these bands agrees within much less than one per cent with the values predicted for a molecule involving C^{13}, and that the mass ratio of 12 to 13 is accurate to one part in 10,000. It now seems probable that the faint band at λ 4752 observed in the spectra of some N-type stars is due to the molecule $C^{13}C^{13}$.

Anderson has devoted considerable time to experimental work with the electro-optic shutter in the attempt to devise a means for studying in detail the phenomena of electrically exploded wires. Since the time involved in the transition from the liquid to the gaseous state is much less than a millionth of a second, the rotating-mirror camera fails to show any of the details of the process, although the magneto-optic shutter used some years ago showed clearly that it is most complicated. Calculation indicates that during a part of the short interval of the explosion, enormous magnetic fields must exist at the surface of the wire.

In cooperation with Doctors Birge and Giauque, Babcock is carrying on measurements on the faint bands due to the isotopes of oxygen, and is continuing a search for other very faint members of the newly discovered system of bands. A new band due to the molecule $O^{16}O^{16}$ has been found and measured, which, although not contributing directly to the investigation of O^{17} and O^{18}, provides the first precise determination of the vibrational energy of the normal oxygen molecule.

Babcock has compared the wave-lengths of 284 lines in the vacuum iron arc measured at the Allegheny Observatory with those derived by the method suggested by him some years ago, according to which the wave-length in vacuum of any line whose terms are known may be derived by a simple computation from the wave-length in the arc in open air. The results of the comparison are most satisfactory, and suggest the use of this method for obtaining standards of wave-length in the region λ 1800–λ 3300, where direct measurements with the interferometer are difficult.

Babcock has made further studies of the correlation in the iron spectrum between the levels of the spectroscopic terms and the groups into which the lines have been classified according to pressure, temperature, dissymmetry, and widening. With increase of any one of these, the levels of the terms are found to increase continuously, the upper and the lower terms following parallel courses.

In the course of his study of radiometers Smith has developed an instrument from which temperature drift and electrostatic charges have essentially been eliminated as disturbing factors, and for which the limit to sensitivity is set by the Brownian movement. The permissible uncertainty due to this source thus sets a lower limit to the size of the suspension. The sensitivity of the radiometer at room temperature has been compared with that at the temperature of liquid air, and the effect of atmospheres of hydrogen, helium and air has been investigated. One of these instruments was used by Smith at the 60-inch telescope on Arcturus, and gave for a region of the spectrum in the vicinity of *Hα* a deflection of 14 mm. at a scale-distance of one meter.

Smith has designed a simple recording microphotometer which uses a short-period radiometer as the light-sensitive element, and two telechron clock motors, one to drive the plate and the other the recording mechanism. In a temporary form such an instrument has given excellent results.

A valuable method for increasing the resolution of close lines on spectrograms and the accuracy of measurement has been devised by Anderson. It consists in the insertion of a cylindrical lens behind the objective of the measuring microscope, with its axis adjusted at right angles to the spectral lines. This lens widens enormously each grain on the photographic plate in a direction parallel to the lines, with the result that the grain disappears. Consequently very high magnification can be used. Tests of the method on a spectrogram of the iron arc taken with a one-meter concave grating show a gain about threefold in resolution and accuracy of measurement. The use of the cylindrical lens also aids greatly the visibility of faint lines.

The ruling machine has been in use throughout the year and during recent months has ruled several excellent 4-inch gratings. Two gratings of larger size with long lines, although quite usable, are not of the very finest quality owing to disturbances during the period of ruling. The diamond points have in all cases been shaped to concentrate light in the desired orders.

Preparations for Dr. Michelson's measurement of the velocity of light through a line of pipe exhausted to a low pressure are nearly completed. The entire line, one mile in length, has been installed and tested throughout, and the optical system with its controls has been adjusted and operated with satisfactory results.

OBSERVING CONDITIONS

Observing conditions for the year were slightly above the normal of those recorded during the past 18 years. Solar observations were made on 312 days and stellar observations on 285 nights. The 60-inch reflector was in use during 2338 hours as compared with an average of 2249 hours.

The winter season was exceptional in the late arrival of the winter storms and the remarkably heavy snowfall. Between July 1, 1929, and January 7, 1930, the total precipitation was only 0.3 inch. Successive snowstorms then gave a total of 104 inches for the season, an amount which has been exceeded only once in the history of the Observatory. The snowfall during a single storm in January reached 55 inches. The total precipitation for the year was 23.24 inches, about 8 inches below the average for 26 years. The maximum temperature of 93° F. was recorded on September 15, 1929, and the minimum of 18° F. on February 24, 1930. Meteorological observations have been continued regularly throughout the year, and special observations have been made at definite hours of the day and night for the use of the air-mail service.

The following table compiled from the records for the 60-inch telescope gives the observational data for this instrument throughout the year.

Public interest in the use of the 60-inch telescope for visual observations on Friday evenings has increased steadily, and 6621 visitors have used the although moderate magnetic storms occurred on November 3–5 and December 3–5. At the time of some notable spot-groups observed in March and July 1929, the magnetic activity was greater than it was near the end of the year.

Mean number of sun-spot groups observed daily

Month	Daily number			Month	Daily number	
	1928	1929	1930		1928	1929
January	6.8	5.2	6.7	July	6.7	7.0
February	6.3	5.9	6.2	August	7.9	6.7
March	6.9	3.7	3.4	September	5.9	4.1
April	6.9	4.7	4.0	October	6.0	3.9
May	5.4	5.4	3.3	November	4.8	6.4
June	7.1	8.0	3.3	December	5.0	11.4
				Yearly average	6.3	6.0

In cooperation with the Harvard and Yerkes Observatories, Mount Wilson has supplied observations on 32 days to supplement the records of areas and positions of sun-spots published by the Naval Observatory in the Monthly Weather Review.

Character figures which serve as an index of solar activity have been sent regularly to Zürich in accordance with the plan formulated by the Solar Physics Committee of the International Astronomical Union. A set of scale plates has been selected for the calcium flocculi and for both dark and bright hydrogen flocculi, and all estimates of character figures have been made by comparison with these standards. In this way it is believed that a uniform scale is being maintained. Estimates for the calcium flocculi have been made on 304 days, and for hydrogen flocculi on 299 days. These character figures and a similar index for the terrestrial magnetic activity, obtained from the daily magnetic records, are published in Terrestrial Magnetism and Atmospheric Electricity.

SUN-SPOT POLARITIES

Records of the direction of polarity and the intensity of the magnetic field in sun-spots were made on 324 days in 1929, with the results indicated in the accompanying table. "Regular" groups in the northern hemisphere have S (south-seeking), or negative, polarity for the preceding spots, and N polarity for the following spots, while in the southern hemispheres the reverse is true. Complex groups, unipolar spots for which there was no indication whether they were preceding or following members of a group, and all groups for which the polarity observations were incomplete are given in the last column.

Hale has resumed the study of the magnetic fields in sun-spots and the general magnetic field of the sun, aided by the special facilities of the Solar Laboratory in Pasadena and by the new Zeiss recording microphotometer. The comparative use of two very different methods of measurement, and the utilization of some improved methods of procedure, lead him to hope that he may at least partially offset some of the unavoidable delays experienced in the development of this investigation.

Hemisphere	Polarity		
	Regular	Irregular	Unclassified
North.	136	2	36
South....	135	6	31
Whole Sun .	271	8	67
Total.. . .		346	

Reference has already been made to the volume on the polarity of sunspots by Hale and Nicholson. The text and the selection of illustrations have been completed, and it is expected that the volume will be published during the coming year.

THE SPECTROHELIOSCOPE

In continuation of his studies with the spectrohelioscope, Hale is describing some of the results of his work in a series of papers entitled, *The Spectrohelioscope and Its Work*, two of which have already appeared as Mount Wilson Contributions Nos. 388 and 393. A special appropriation by the Carnegie Institution has enabled the Mount Wilson Observatory to build six of these instruments, with cœlostat, second mirror and lens, for use at the Royal Observatory, Greenwich; the Royal Astrophysical Observatory at Arcetri, Florence; the Observatory of the American College at Beirut, Syria; the Solar Observatory at Kodaikanal, India; the Government Observatory at Wellington, New Zealand; and the Apia Observatory at Apia, Samoa. Since each of these instruments constitutes a small but efficient solar observatory, capable of revealing the brilliant eruptive phenomena on the sun's disk which have been found to be forerunners of terrestrial magnetic storms, auroras and other geophysical disturbances, it is to be hoped that the means thus provided for keeping the solar atmosphere under nearly constant observation may lead to a better knowledge of the exact relationship between terrestrial and solar phenomena.

Other observatories actively interested in this broad problem are procuring exactly similar instruments, made by Howell and Sherburne of Pasadena, and tested in the Solar Laboratory before shipment. In addition to the institutions listed in last year's report, the following have ordered spectrohelioscopes: the Detroit Observatory, Ann Arbor; the University of South Dakota; the Adler Planetarium and Astronomical Museum in Chicago; and the National Research Institute of Astronomy, Nanking, China. Since several other institutions and individuals are planning to install spectrohelioscopes in the near future, there is reason to expect that ultimately not even the local vicissitudes of the weather will interfere with an efficient program of observation, organized in conjunction with observatories engaged in the study of terrestrial magnetism, the aurora, and variations in radio-receptivity.

THE SPECTRUM OF SUN-SPOTS

As a part of her work toward the requirements for a higher degree at the University of California Miss Charlotte E. Moore has been making a careful study of all the lines occurring in sun-spot spectra which arise from atomic transitions. For this purpose she is using the rich material collected during past years at Mount Wilson. The investigation includes estimates of intensity in the spot spectrum on Rowland's scale, measurements of wave-length and identification of lines, classification according to temperature and excitation potential, and multiplet designations where such are possible. The total number of lines included exceeds 6,000.

Mr. R. S. Richardson has been making a special study of the spectrum of sun-spots in the region λ 4500–λ 5500. He has measured the wave-lengths and estimated the intensities of all lines between λ 4900 and λ 5400, and has secured additional data from the measures of Adams made a number of years ago. Evidence is found of the presence in the spot spectrum of the bands of AlO at λ 4648 and λ 4842. The possible presence of the spectrum of molecular hydrogen is being investigated further.

Richardson has compared the distribution of intensity in the Swan band at λ 5165 with that calculated from theory, using the spot temperature of 4800° K determined by Pettit and Nicholson. A satisfactory agreement between the two can be obtained by assuming a particular value for the angular momentum parallel to the inter-nuclear axis of the molecule. From this value and the observed intensities of the band lines in the sun's disk the temperature of the reversing layer is found to be about 5400° K.

SOLAR ROTATION AND CENTER-LIMB DISPLACEMENT

St. John, assisted by E. F. Adams, has continued measurements of the solar rotation by the spectroscopic method. The measures are at present limited to the solar equator, and to serve as a check on the results are made in a portion of the spectrum in which atmospheric lines are present. The equatorial velocity, after apparently decreasing for a number of years, seems to have reached a minimum and shows a slight tendency to increase.

Measurements of changes in wave-length between the center and limb of the sun, and of the absolute wave-lengths of lines at the limb, are being continued by St. John with especial reference to the residual limb-effect after elimination of the relativity displacement. The change in the contours of spectral lines between the center and the limb is also under investigation.

MULTIPLETS AND EXCITATION POTENTIAL IN THE SOLAR SPECTRUM

Two statistical applications by St. John to solar phenomena of the valuable material he has collected through measurements of wave-length and line-displacements have led to results of interest. In the first he shows that all the lines of a given multiplet have equal displacements to the red in the solar spectrum. This supports the assumption implied in the calculation of the theoretical intensities of the components of a multiplet, that a definite mass of absorbing gas is concerned, each part of which contributes its proportion to the individual lines of the multiplet.

From a preliminary investigation of the part played in the solar spectrum by the various levels of excitation potential from which atomic lines arise, St. John concludes that excitation potential determines: (1) the possibility and relative probability of the occurrence of a multiplet in the sun's spectrum; (2) the relative heights of the absorbing layers above the photosphere; (3) in combination with transition probability, the maximum line-intensity in a multiplet; (4) the temperature classification.

THE INFRA-RED SOLAR SPECTRUM

Babcock has continued from time to time routine work on the program of the infra-red spectrum outlined previously. The measurement and reduction of all the spectrograms on hand have been completed, and the results so far obtained have been summarized in a preliminary table of wave-lengths extending to λ 11,634. Further description of this material will be deferred until the completion of such observational work as can be done with the equipment now in use, when it is planned to publish the data in full with the addition of much supplementary material compiled by Miss Moore.

NUMBERS OF LINES OF VARIOUS INTENSITIES IN THE SOLAR SPECTRUM

Babcock has completed a study of the numbers of atomic solar lines of each intensity in Rowland's table of the solar spectrum. About 18,700 lines have been counted between λ 2975 and λ 10,218, with results which indicate some apparent peculiarities in the occurrence of the weakest lines. Since the best modern spectrograms fail to show large numbers of the lines listed by Rowland with intensity 0000, or −3 in current notation, the need of a thorough review of the solar spectrum with a large concave grating of the finest quality is emphasized.

SPECTRAL ENERGY CURVE OF SUN-SPOTS

In 1922 Pettit and Nicholson used a monochromator and thermocouple at the 150-foot tower telescope to measure the ratio of the energy in the nucleus of a sun-spot to that of the photosphere. They have continued this investigation at intervals since that time, employing a one-meter concave grating and a telescope with speculum mirrors throughout to extend the measurements to the extreme ultra-violet. The measures show that the ratio varies in a nearly linear manner from 0.21 at λ 0.3 μ, to 0.80 at λ 1.7 μ, after which it is nearly constant. Depressions at λ 1.38 μ and λ 1.9 μ are perhaps reflected errors due to the deep water-vapor absorption bands at these points. When the solar energy for the center of the sun is multiplied by the spot-photosphere ratio for each wave-length, a sun-spot energy curve results which is much like that of the photosphere and corresponds in total energy to a black body at 4860° K. Even if the solar energy curve is taken as that of a black body, the resulting sun-spot energy curve differs from that of a black body chiefly in the visual and violet regions. In this case the black body energy curve which fits best corresponds to a temperature of 4750° K. The water-cell absorption for a spot in average position on the sun's disk is 0.50 magnitude, which gives a temperature of 4720° K. These results indicate that the temperature of the umbra of a sun-spot is probably near 4800° K or possibly a little less.

The distribution of energy across the spots has been determined with a thermocouple having a pinhole diaphragm. This is found to fall off continuously in passing from the photosphere to the umbra. Direct measurements on six different spots of medium size in October 1921 gave a ratio of spot to photosphere of 0.471. The spectral distribution curve of the spot-photosphere ratios gives a value of 0.477 for the ratio of the total energies. No large spots have as yet been measured.

The rate of radiation at the center of the sun's disk is 16 per cent greater than that of integrated sunlight. This makes the value at the center 2.25 cal cm^{-2} min^{-1}, and the corresponding temperature calculated from the fourth-power law 5955° K.

ULTRA-VIOLET SOLAR RADIATION

Pettit has continued as heretofore the measurement on clear days of the ratio of the solar energy at $\lambda\,0.32\,\mu$ transmitted by a silver film to that at $\lambda\,0.5\,\mu$ transmitted by gold. The monthly average reached the high level of 1.52 in January 1930, the highest values previously being 1.57 in November 1925 and 1.51 in February and April 1927. The lowest monthly average was 1.15 in April 1930, the lowest previous values being 1.00 in June 1924 and 1.12 in September 1928. So far all tests indicate a constant transmission for the gold and silver films upon which the measurements depend.

The study of the ultra-violet spectrum of the sky has been continued by Pettit with a quartz spectrograph made of the optical parts of a Bausch and Lomb quartz monochromator crossed with one of these monochromators. This utilizes a much larger portion of the sky during the exposure than has been used previously. During the first week of January 1930, a three-day exposure on the northern sky at an altitude of 57° gave spectra down to $\lambda\,0.295\,\mu$, while similar exposures made in 1928 at the winter solstice with a grating spectrograph gave a limit of $\lambda\,0.297\,\mu$. Although exposures made at the summer solstice with the new apparatus give much stronger spectra, the ultra-violet limit of $\lambda\,0.293\,\mu$ observed in the sky spectrum with the grating in 1929 has not been appreciably lowered. A comparison of the intensity of the sky spectrum in Pasadena with that on Mount Wilson near the ultra-violet limit is now in progress.

CONTOURS AND INTENSITIES OF SOLAR SPECTRUM LINES

Three separate investigations of the spectrophotometric contours and residual intensities of solar spectrum lines are in progress. All involve the use of the recording microphotometer for measurement but employ different methods of standardization. St. John is engaged in the study of the components in a selected list of doublets, triplets and multiplets containing many lines. Mr. Woolley is giving especial attention to the lines in the region $\lambda\,4500$–$\lambda\,4600$ and a few chosen multiplets, while Dr. Shane is applying his interference method mainly to lines in the less refrangible part of the spectrum. It is thought that all of these investigations will throw light on the general question of multiplet intensities in absorption spectra, the interpretation of Rowland's intensities on an absolute scale, and the problem of the relative abundance of the various atomic states in the solar atmosphere.

A CHART OF THE SOLAR SPECTRUM

A set of spectrograms of the solar spectrum from its ultra-violet limit near λ 3000 to λ 6600, with the spectrum of the iron arc in accurate juxtaposition, has been made by King with the 15-foot concave-grating spectrograph. Enlargements of these spectrograms by Ellerman, with a wavelength scale superposed, form a useful chart for the ready identification of both solar and iron arc lines.

THE TOTAL SOLAR ECLIPSE OF APRIL 28, 1930

An expedition from the Observatory, including Babcock, Dunham, Hickox, Nicholson, Pettit and Smith, assisted by Mrs. Dunham and Mr. E. R. Hoge, observed the solar eclipse of April 28 from a station near Honey Lake, California. The station was located after a survey made in the latter part of March by Nicholson and Pettit, who determined accurate values of the latitude and longitude of several points near the eclipse path. Owing to thin clouds during totality, no photometric results of value were obtained, but some of the spectroscopic observations were more successful than was anticipated under the conditions.

Two investigations were planned by Pettit and Nicholson, the photometry of the corona, and the photometry of the changing crescent during the few seconds near totality, to determine the law of darkening at the limb of the sun. In the first problem an electrically operated shutter controlled by a pendulum was used, but the cloudy sky left on the photographs only the impression of Baily's beads. These were sufficient to indicate that the station was on the narrow eclipse path. In the second investigation a motion-picture camera was used with a mechanically operated focal-plane shutter of the slit type, which gave an exposure of fixed duration independent of the speed of operation of the camera. The whole instrument was placed in a fixed position and light was supplied from a cœlostat with fused quartz mirror. The results, while vitiated by clouds, indicate the feasibility of the method.

The chief investigation planned by Babcock was the study of the flash spectrum in the infra-red with low dispersion produced by a special grating made on the ruling machine. These observations, which require great intensity of light, were unsuccessful, although a few of the strongest lines are just visible on the photographs.

One of the spectrographs designed by Anderson for the Sumatra eclipse of 1928 was utilized by Smith. It includes a 10-foot concave grating and a moving plate-holder similar to that first used at eclipses so successfully by Campbell. During eclipse an image of the solar crescent is projected on the plane of the slit, which is made very wide, and a narrow occulting bar is used. Thus a very narrow spectrum is formed in which the line-width is determined by the width of the crescent, that is, by the amount of luminous material not covered by the moon. A motor drives the photographic film parallel to the spectral lines so that a continuous record is obtained of the change in spectrum as the eclipse progresses. From this record the variation with altitude of the number of any particular kind of atom in the solar atmosphere can be derived. Owing to conditions at the time of the eclipse the film which was obtained shows only about 300 measurable lines between λ 3900 and *Hα*, including 12 lines of the Balmer series of hydrogen. Unfortunately the intensity of these lines at any one point depends far more upon some momentary cloud pattern than upon the state of the eclipse at the corresponding time.

Dunham photographed the flash spectrum with another spectrograph designed several years ago by Anderson. A minified image is formed by a concave mirror of one-meter radius, after which the light is rendered parallel by a mirror of 21.5 feet focal length and then falls on the concave grating of the same radius. The spectrum made with this arrangement has excellent definition and shows more than 2000 lines between λ 3322 and λ 6562. As the film was photometrically standardized, it should be possible to measure the relative intensities of lines in multiplets. During eclipse the apparent diameter of the moon so nearly matched that of the sun that the crescents in the flash spectrum extend nearly half around the sun, with variations of intensity caused almost entirely by differences in the altitude of the mountains and valleys at the edge of the moon. If the topography can be determined from the motion picture film taken by Nicholson and Pettit or from measurements made directly on the moon at a similar libration, it should be possible to measure on this plate the intensities of the flash lines at various heights in the chromosphere.

A series of spectra taken in rapid succession by Mrs. Dunham with a replica grating and a roll film camera shows the hydrogen and calcium atmosphere completely surrounding the sun for several seconds before and after totality. Several spectra of different intensities were obtained at each exposure by multiple reflections from speculum metal and unsilvered glass. It had been hoped that by this means it would be possible to follow the change in the energy distribution of the continuous spectrum near the limb of the sun, but thin clouds prevented such a study.

LUNAR AND PLANETARY INVESTIGATIONS

Much of the observational work on the moon during the year has been conducted in accordance with the plans and suggestions of Dr. F. E. Wright, of the Geophysical Laboratory of the Carnegie Institution, Chairman of the Committee on the Study of the Surface Features of the Moon. Dr. Wright spent the months of September and October 1929 in Pasadena, and was actively engaged in developing methods for investigating a wide variety of lunar problems.

A method for constructing a large-scale photographic map of the moon has been developed by Dr. Wright and Pease, and considerable experimental work has been carried on in Pasadena to test its practical operation. It consists essentially in projecting a positive or negative transparency of the moon upon a sphere coated with a white diffusing material, and then photographing the sphere with the projected image along a standard line of sight. Since photographs of the moon are taken along various lines of sight, the reduction to a standard direction requires corrections for libration and parallax. These may be made by the aid of special projection charts and test plates constructed by Dr. Wright during his visit.

Little difficulty was experienced in coating a 15-inch bronze globe with a uniform surface of magnesia, but attempts to photograph the projected lunar image were seriously affected by vibrations transmitted through the floor of the optical shop in which the apparatus was assembled. The results obtained show, however, the feasibility of the method and provide an estimate of exposure times. The apparatus will be transferred to Mount Wilson this summer and erected near the dome of the 100-inch telescope where it will be free from difficulties with vibration. The two concave mirrors used in the projection system have been figured in the optical shop. Both have focal lengths of 67.5 feet corresponding to one-half the equivalent focal length of the 100-inch telescope at the Cassegrainian focus at which the original negatives are usually made.

A small quartz spectrograph containing the optical parts of a Bausch and Lomb monochromator is being used to determine the amount of polarized light reflected from different features on the moon's surface. A quartz Wollaston prism with a slope angle of 30°, cemented with a thin film of glycerine, is mounted on a slide in the parallel beam of light between the collimating lens and the first prism, and may be inserted or withdrawn at will. On insertion, two spectra are formed at the focus of the camera lens, the first by light vibrating in one plane, and the second by light vibrating in a plane normal to the first. When the prism is withdrawn a single spectrum is formed midway between the two polarized spectra. The spectrograph is mounted in the center of the tube of the 100-inch telescope in order that the image may be formed with but a single reflection at nearly normal incidence. The apparatus may be rotated to any position angle with reference to the lunar terminator.

DIRECT PHOTOGRAPHY

Twenty-two photographs of the moon were made by Pease and Dr. Wright in September 1929 with the 60-inch telescope. During the following November, Pease, assisted by Joy and Sanford, obtained two series of photographs of selected regions on the moon with a motion-picture camera at the Newtonian focus of the 100-inch reflector. The first series showing a portion of Mare Crisium and the mountainous area to the eastward was obtained on November 18. The exposures were made at intervals of 8 seconds over a period of 5 hours and 40 minutes, except for short intervals when the definition was momentarily poor or the registration incorrect. The second set of photographs on November 19 shows an area including many craters near Janssen. Both series when passed through a motion-picture projector illustrate in a striking way the effect of changes in illumination due to the moon's rotation. These films were shown at the Annual Exhibit of the Carnegie Institution at Washington in December

LUNAR RADIATION

In continuation of their investigations on lunar radiation, Pettit and Nicholson have compared the values of the temperature given by their radiometric measurements with those derived by other methods.

The temperature of a planet is given by the general equation

$$\log T = 2.612 - 0.1\,(\bar{m}_r - \Delta m_r),$$

where m_r is the radiometric magnitude of a square second of planetary heat and Δm_r is the absorption loss in the atmosphere and the telescope. The temperature of the sub-solar point on the moon computed by this equation from observations of m_r at full moon is 407° K, while at quarter phase it is 358° K, a result which indicates that the distribution of energy about a unit surface area does not follow the cosine law. The value of $\bar{m}_r$ to be used in the above equation is that corresponding to the mean spherical distribution of energy. This was obtained by measuring the planetary heat from the sub-solar point as it passed over the earthward face of the moon between first and last quarters during the summer and autumn months. From this distribution curve of planetary heat about the sub-solar point the mean spherical rate of emission E was found to be 1.93 cal cm^{-2} min^{-1}, and the corresponding temperature 391° K.

The temperature of the sub-solar point may also be computed from the solar constant E_R, the reflected solar radiation E_r, and conducted planetary heat E_e, according to the formula,

$$T = \sqrt[4]{\left(\frac{E_R - E_r - E_e}{\eta\sigma}\right)}.$$

E_r was determined during the measurement of $\bar{m}_r$ and found to be 0.24 cal cm^{-2} min^{-1}, while E_e was estimated from the variation of lunar temperature during a lunar eclipse to be less than 0.1 cal cm^{-2} min^{-1}. That the emissivity η may be taken as unity is indicated by a comparison of the amount of planetary heat transmitted by a plate of fluorite. This equation, in which σ is the Stefan constant, gives $E=1.61$ cal cm^{-2} min^{-1} and $T=374°$ K.

A study of this discrepancy of 17° between the lunar temperature computed from direct measurements of the emitted radiation and from the solar constant after measuring the lost energy indicates that the tabular values of Δm_r computed from the laboratory measurements of water-vapor transmission of long-wave radiations are too great. A table of corrections, $\Delta m'_r$, has been devised which will make temperatures computed with the first equation agree with those from the second. This indicates that our atmosphere is about 19 per cent more transparent between 8 μ and 14 μ than Fowle's transmissions allow. The effect of this correction is to reduce the temperature computed from the radiation measurements of Mercury 45° C., Venus 9°, Mars 10° and the moon 17°. Mercury, like the moon, has always yielded a temperature higher than the solar constant will allow, and the application of $\Delta m'_r$ will bring it nearly into line with the solar-constant temperature.

From the distribution curve of reflected light about the sub-solar point and the drift curves made with the water-cell in the beam the formula

$$E_r = K\frac{0.46 \sec^2 \frac{i}{2}}{0.46 \cos\theta + \sin\theta}$$

was derived, where E_r is the reflected light and i and θ the angles of incidence and reflection, respectively. The laws of Lambert, Lommel and Seeliger, and Euler can not be made to fit the observational material.

A comparison of the planetary heat transmitted by the fluorite plate with that transmitted by the atmosphere alone shows that if silicates are present on the lunar surface, they are in a finely divided or porous state.

A final reduction of all the observational material gave the following constants of lunar radiation and temperature under standard conditions.

(1) Temperature of the sub-solar point, 374° K.
(2) Temperature of the dark side of the moon, less than 120° K.
(3) Radiometric magnitude of the total radiation from the full moon, −14.8.
(4) Radiometric magnitude of the reflected radiation, −13.3.
(5) Radiometric albedo of the moon, 0.093.
(6) Temperature 0.05 radius from the limb before eclipse, 342° K.
(7) Temperature 0.05 radius from the limb after 2^h 40^m immersion in the umbra of the earth's shadow, 156° K.

TEMPERATURE OF THE PLANET MARS

The data given in the preceding section on the transparency of the atmosphere in the region 8–14 μ have been used by Pettit and Nicholson to construct a new transmission curve for this region. A set of atmospheric absorption coefficients for various temperatures has been computed with this curve and the problem of planetary temperatures attacked anew. A new reduction of the observations on Mars, made in 1924 with a thermocouple having small receivers for exploring the image of the planet, gives for the temperature of the sub-solar point at perihelion 294° K. The observations of 1926 reduced to perihelion give 297° K. The great eccentricity of the orbit would make the temperature at aphelion 27° lower.

PHOTOGRAPHY OF SATELLITES

During the opposition of 1929 Nicholson, assisted by Mayall, secured a number of photographs of the Ninth Satellite of Jupiter and used the positions in calculating an improved ephemeris.

Christie has made a photographic search for additional satellites of Uranus and Neptune but has found no new objects as bright as the nineteenth magnitude. At the request of Professor W. H. Pickering several photographs of the region about Saturn were made by Christie in a search for Pickering's predicted satellite. These plates have been sent to Professor Pickering.

OBSERVATIONS OF THE NEW PLANET PLUTO

In the winter of 1919 M. L. Humason made with the Cooke 10-inch photographic refractor a series of photographs centered on the ecliptic in a search for the trans-Neptunian planet predicted by W. H. Pickering and Percival Lowell from the perturbations of Uranus and Neptune. The fields observed covered the positions predicted from all the mathematical solutions. In the following year the search was continued with the 60-inch reflector, but the observations were limited to a zone one and one-half degrees wide on either side of the ecliptic. The photographs were examined with an improvised "blink" comparator, but the planet was not detected, although many asteroids and a few variable stars were observed. The most careful examination naturally was made in the immediate neighborhood of the ecliptic.

After the announcement of the discovery of the new planet by the Lowell Observatory, Nicholson undertook the re-examination of the 10-inch refractor plates, but it was not until the area to be covered could be limited by means of approximate positions of the orbit plane and two provisional ephemerides that he was able to find the images of the planet. They appear on four of the negatives within 1° of Pickering's predicted longitude, but at a distance of nearly 4° from the ecliptic in a portion of the Milky Way extremely rich in stars.

The position of the planet as measured on these photographs, together with positions from observations made by Mayall in March and May 1930 with the 60-inch reflector, and the Lowell Observatory positions of January 1930 were used by Nicholson and Mayall in a computation of the orbit. The resulting period was found to be 252 years; the eccentricity of the orbit 0.26; the semi-major axis 40 astronomical units; and the time of perihelion passage 1988.6.

Nicholson and Mayall are at present engaged in determining the approximate mass of the planet on the assumption that the perturbations of Uranus and Neptune which were used by Pickering and Lowell in their computations were due wholly to the new planet.

RESEARCHES ON NEBULÆ

As a voluntary observer, Dr. Duncan participated in the work of direct photography with the reflectors on seven nights during the year.

In addition to photographs made for use in the investigations described below, he obtained a good negative, with an exposure of nine hours at the Newtonian focus of the 100-inch telescope, on the northern part of the nebulous wreath in Cygnus. It shows a number of faint nebulous filaments not catalogued in the N.G.C. These are evidently related to the well-known Veil nebulæ N.G.C. 6960 and 6992, which form the brighter parts of the wreath.

Most of the direct photographs of nebulæ made during the year are by Hubble, with some assistance from Mayall. The long-exposure spectrograms of extra-galactic nebulæ were obtained by Humason and Pease. These were measured by Humason and Miss MacCormack.

NEBULAR SPECTROSCOPY

Spectroscopic observations of 15 extra-galactic nebulæ have been made with the 100-inch telescope during the past year. Over half of the nebulæ observed are members of the five clusters for which data are given in the table on page 162 and are important additions to the small group of cluster nebulæ previously observed. The remainder are isolated nebulæ having apparent velocities ranging from +750 to +4100 km./sec. The spectral types have been estimated for all the nebulæ thus far observed. The spread in type is very small; excepting N.G.C. 205, which has been classified as F5, all the nebulæ having absorption spectra are included within the limits G0–G4.

The single nebula observed in the Ursa Major cluster is the faintest and has the largest red-shift thus far observed. The distance of this object obtained from the apparent velocity of +11,500 km./sec. is 75 million light years and agrees almost exactly with that previously assigned to the cluster by Hubble on the basis of the apparent brightness of the nebulæ involved.

The spectrogram of this faint object was made with the aid of a short-focus spectrograph objective designed by Dr. W. B. Rayton of the Bausch and Lomb Optical Company for the Astrophysical Observatory and Laboratory of the California Institute. The lens is an eightfold enlargement of a microscope objective and has a focal length of 32 mm., an aperture of 50 mm., and a focal ratio of F/0.6. As used with two prisms, the dispersion is 418 A per millimeter at λ 4350. The exposure time required was 45 hours. Observation with the 3-inch camera and single prism previously in use would have required 100 hours or more.

A plate of Nova Aquilæ 1918, obtained by Dr. Duncan with the Hooker telescope June 30, 1930, shows that the nebulous envelope disclosed on earlier plates is still growing fainter and enlarging at a uniform rate, and is now 23″ in diameter.

VELOCITY-DISTANCE RELATION AMONG EXTRA-GALACTIC NEBULÆ

The velocity-distance relation among extra-galactic nebulæ, determined last year from the data for the nearer nebulæ, has been fully confirmed by Hubble and Humason with the aid of new data which extend the observed range about 12 times, or to some 24,000,000 parsecs on the provisional scale of distance. The relation is closely linear and amounts to about 500 km./sec. per million parsecs.

Velocities are now available for 58 isolated nebulæ and 22 nebulæ in 5 clusters. Distances based upon stars involved are known for 21 isolated nebulæ and one cluster (Virgo), and distances based upon median magnitudes of component nebulæ have been derived for four clusters. The remaining 37 isolated nebulæ in which no stars can be seen were divided into groups whose mean distances have been derived from mean apparent magnitudes. With one exception, N.G.C. 4865 in the Coma cluster, readily explained as a field nebula seen in projection, the velocities and distances are so closely correlated that the apparent velocity-shifts provide what appears to be a new and very important method of determining great distances. As an example of the possibilities opened by the method, the luminosity function for the isolated nebulæ has been derived and found to be comparable with that for the nebulæ in clusters.

PHOTOGRAPHIC MAGNITUDES OF NEBULÆ

The need for reliable magnitudes of nebulæ has led Hubble to make extensive investigations of the photometric problems involved. It is necessary in general to use extra-focal images comparable in size with the images of the comparison stars, since the photometry of surfaces differs widely from that of point sources, and even for surfaces systematic effects are found which depend on the size of the image. Moreover, the total luminosity of a nebula increases with exposure time at a rate which depends upon the central luminosity and the luminosity gradient. The effect is most conspicuous among the globular nebulæ and diminishes along the sequence of classification until, with the later-type spirals, it is unimportant.

For the present, extra-focal exposures of one hour on Eastman 40 plates at the Newtonian focus of the large reflectors are used as standards, and provisional corrections have been determined for exposure time, central luminosity, class of nebula and type of telescope employed. In view of the complexity of the problems, however, a sequence of nebulæ has been selected in the Virgo cluster by means of which it is hoped that the magnitude systems of different observers may be inter-compared. Until a significant system is definitely established, distances derived from apparent luminosities must be considered as provisional.

CLUSTERS OF NEBULÆ

Provisional distances based on brightness have been derived by Hubble for three clusters of nebulæ in addition to the Coma cluster, mentioned in last year's report, and the Virgo cluster, whose distance was calculated from stars involved in ten of the component nebulæ and from mean dimensions of nebulæ of various types. The results are in the accompanying table.

Cluster	No. of nebulæ	Diameter	Median pg. mag	C.I.	Distance in parsecs	Mean velocity	No. of vel.
						km/sec.	
Virgo	800±	12°0	12.5±	+1.2±	2×10^6	+900	7
Pegasus	100	1.0	15.5	....	8	3400	5
Perseus	500	2.0	16.4	1.4	10.5	5100	4
Coma	800	1.7	17.1	1.2±	16	7200	3
Ursa Major	300	0.7	17.9	1.2	24	11500	1

The cluster in Pegasus (N.G.C. 7619, etc.) is the least conspicuous of the list and should probably be classed simply as a group. The great clusters, of which only six or eight have been certainly identified, appear to be of a definite order of dimensions (diameter about 4 x 10^5 parsecs) and to consist of several hundred nebulæ each, the earlier types predominating. The Virgo cluster seems to be unique in containing a considerable number of spirals, although the percentage is still much less than that found among isolated nebulæ.

COLORS OF NEBULÆ

The calibration of apparent photographic magnitudes of nebulæ in terms of distance requires a knowledge of color indices, since the zero point is based on Holetschek's visual magnitudes of the brighter nebulæ whose distances have been determined from the stars involved. For this reason photovisual magnitudes have been derived for many nebulæ, including those in four of the clusters. For this purpose extra-focal exposures two hours in length through light color filters were made with the large reflectors. The provisional results are in fair agreement with Holetschek's scale over the region compared, 9.0 to 12.0. The differences pg. — pv., which serve to reduce the photographic magnitudes to Holetschek's scale, are a combination of true color indices and any systematic errors in the pg. and pv. magnitude scales. Exposure ratios, derived by Seares's method, indicate that the differences agree approximately with the color indices and that the systematic scale errors are small.

In high galactic latitudes the color indices appear to be of the order of +1.1 or +1.2 while in the Perseus cluster, at −13°, they are about +1.4. Since the spectral types of the nebulæ average about G2, these results suggest a color excess which may vary with galactic latitude and not with distance. The suggestion has important implications with regard to the absorption and scattering of light within the galactic system, but in view of the provisional nature of the results, the question is being investigated in a more thorough manner.

GENERAL SURVEY OF NEBULÆ

A general survey of the sky to declination −25° has been completed by Hubble. This includes about 500 fields uniformly distributed in galactic coordinates, photographed with exposures of one hour on Eastman 40 plates with the 100-inch and 60-inch reflectors indiscriminately. About 10,000 nebulæ have been counted on the plates, and the duplication is sufficient for the derivation of the corrections necessary to reduce the material to a homogeneous system. These data, together with a similar number of plates centered on particular objects and having exposures ranging from a few minutes to several hours, are being used to determine the distribution of nebulæ over the sky and the rate at which the numbers per unit area increase with the exposure time.

Preliminary results already indicate a very irregular zone of avoidance along the Milky Way, a scarcity of nebulæ along the borders of this zone, and a fairly uniform distribution in the higher latitudes, with frequent groups and occasional clusters superimposed. The data from the 100-inch and 60-inch reflectors separately indicate that, in the higher latitudes, the numbers of nebulæ increase with the exposure time as though they were distributed in space with approximate uniformity. A similar result has been derived from the counts of nebulæ made by Curtis on Crossley reflector plates, supplemented by data on exposure times and quality of images made available through the courtesy of the Director of the Lick Observatory.

DISTRIBUTION OF LUMINOSITY IN ELLIPTICAL NEBULÆ

An investigation of the distribution of luminosity in elliptical nebulæ has been completed and published (Mt. Wilson Contribution No. 398). Luminosity curves along various axes of 15 elliptical nebulæ, derived from transparency curves of photographic images measured with a Koch registering microphotometer, follow the general trend of the formula

$$\log I = \log I_0 - 2 \log\left(\frac{r}{a} + 1\right)$$

where I is the luminosity, I_0 the central luminosity, r the distance from the center, and a a parameter varying from nebula to nebula, and in any one nebula, directly with the radii along which the luminosities are measured.

The corresponding curve which represents the three-dimensional distribution of luminosity within the nebulæ has been derived in a manner analogous to that used in the case of globular clusters. This curve exhibits a suggestive similarity over a considerable range with that expressing the distribution of density in an isothermal gas sphere.

MISCELLANEOUS STELLAR INVESTIGATIONS

TRIGONOMETRIC PARALLAXES

Van Maanen has continued the measurement of trigonometric parallaxes, obtaining during the year 91 plates with 159 exposures at the primary focus of the 100-inch reflector, and 112 plates with 211 exposures at the Cassegrainian focus of the 60-inch reflector. Parallaxes have been derived from 17 fields. For eight stars the results give absolute photographic magnitudes fainter than +10. These are collected in the accompanying table.

	Appt. pg. mag.	α 1900	δ 1900	Abs. π	M	μ
Ross 451 .	13 5	$11^h\ 34^m\ 42^s$	+67° 53′	0″.045	11 8	3″20
Furuhjelm 46	10 8	17 9 12	+45 50	0 148	11 7	1 59
Wolf 901 .	13 2	20 54 6	+ 3 10	0 036	11 0	1.11
Ross 200 .	15 3	21 36 33	+53 41	0.039	13 3	0 60
Wolf 1328. ...	13 9	22 3 52	− 8 23	0 047	12 3	0.71
Companion	15.4	22 3 52	− 8 23	0 049	13 8	0 71
Wolf 1342. ..	14 3	22 4 13	− 4 52	0 029	11 6	0 54
B.D. +43°4305.	11 3	22 42 30	+43 48	0 213	12 9	0 86

The only star in the list which has a trigonometric parallax by another observer is B.D. +43°4305, for which the Leander McCormick Observatory gives a value of 0″.208. Spectroscopic parallaxes determined by Adams for Furuhjelm 46 and B.D. +43°4305 are, respectively, 0″.115 and 0″.240. The companion of Wolf 1328 is separated from the principal star by only 1″.9.

The considerably larger probable errors for plates taken at the Newtonian focus of the 100-inch as compared with those obtained at the Cassegrainian focus of the 60-inch reflector are due to the asymmetry of the images of the comparison stars, and care should accordingly be taken that the mean distance of such stars should not exceed 5′ (Mt. Wilson Contribution No. 391).

PROPER MOTIONS

For the measurement of proper motions van Maanen has obtained 40 plates with 46 exposures, and 83 plates with 128 exposures at the 100-inch and 60-inch reflectors, respectively. In addition Christie has reobserved photographically nearly one-half of the Selected Areas in the northern hemisphere in connection with van Maanen's search for stars of large proper motion.

In the case of the open cluster N.G.C. 2264, two pairs of plates, taken at the 80-foot focus of the 60-inch reflector with a time interval of 11 years, have been measured by van Maanen. The probable errors of the final proper motions in right ascension and declination of the 133 stars are 0″.0028. About 50 stars probably belong to the cluster, which has the absolute motion,

$$\mu_\alpha = -0''.0033 \pm 0''.0007, \quad \mu_\delta = +0''.0019 \pm 0''.0006.$$

The work on planetary nebulæ mentioned in last year's report has been continued. Four pairs of exposures are being measured, with probable errors found to be only slightly larger than 0″.001. N.G.C. 6058, 6543, 6572, 6720, 6804 and 6905 are finished, and their motions range from 0″.004 to 0″.010, which would indicate a mean parallax of about 0″.001.

Four more pairs of plates of the spiral nebula N.G.C. 4051 have been measured, making a total of nine pairs with a mean interval of 10.77 years. The absolute motion found for the stellar nucleus is

$$\mu_\alpha = -0''.003 \pm 0''.0008, \quad \mu_\delta = +0''.015 \pm 0''.0011.$$

Various possible sources of error have been investigated, including magnitude error, hour-angle errors, and one depending on the quadratic terms. None of these seems to have influenced the result materially. If we suppose the motion derived to be of the same order as the radial velocity, we find a parallax of 0″.000073, corresponding to −2.7 as the absolute magnitude of the nucleus, which has a spectrum of the planetary type.

Five pairs of plates of the spiral nebula N.G.C. 5194 (Messier 51) with a mean interval of 13.02 years, give for its absolute motion,

$$\mu_\alpha = -0''.0015 \pm 0''.0010, \quad \mu_\delta = +0''.006 \pm 0''.0011.$$

All of the photographs of the fields mentioned were taken at the 80-foot focus of the 60-inch reflector.

STELLAR PHOTOMETRY

Reference has already been made to the publication of the *Mount Wilson Catalogue of Selected Areas* by Seares, Kapteyn and van Rhijn. The volume appeared from the press at the end of April as Publication No. 402 of the Carnegie Institution and as Volume IV of the Papers of the Observatory.

The reductions for photovisual magnitudes in 43 of the Selected Areas have been continued by Seares and Miss Joyner. Magnitudes to a photovisual limit of about 15.5 are now complete for the zones at declinations +45° and +30°. The calculations are laborious because a second approximation is necessary in order to utilize fully the data afforded by the comparison photographs which connect adjacent Areas. The scale is established partly by diaphragm exposures and partly by polar comparisons, and then strengthened, both in respect to slope and zero point, by averaging the results for three successive Areas. The exposure-ratio photographs available for the 45° and 30° zones are being reduced along with those taken for the derivation of magnitudes. The independent determination of colors from the exposure-ratios gives a valuable control on the magnitudes. The general agreement is satisfactory, although small systematic differences occur in certain cases. The chief difficulties arise from abnormal values of the distance correction for faint stars which are caused by small temperature deformations of the 60-inch mirror and from the correction for gradation which must be applied to the exposure-ratios.

Partly as an aid to those who will observe Eros at the coming opposition, and partly for comparison with existing catalogues, Seares and Sitterly are determining the magnitudes, both photographic and photovisual, of the comparison stars south of the equator given in Kopff's two lists (*A.N.* vol. 224, 387; vol. 226, 33). Most of the stars are between magnitudes 7 and 10 and within a zone 2° wide, centered on the path of the asteroid. The photographs were made by Sitterly with the 10-inch Cooke triplet, and consist of polar comparisons and overlapping intercomparison plates. To facilitate comparisons with various catalogues, the observations have been extended to stars brighter than the seventh magnitude by means of screen exposures.

STELLAR INTERFEROMETERS

The completion of the optical and mechanical work on the 50-foot interferometer has made it possible for Pease to give a part of his time to the adjustment of the instrument and the alignment of the optical system. Fringes have been observed readily with the outer mirrors at separations of 25 and 34 feet, and there is no reason to believe that they will not be well seen up to the full separation of 50 feet. Observations of α Orionis and α Boötis under very moderate conditions of seeing are in good agreement with those made with the 20-foot interferometer.

A gradual separation of the two images as the interferometer turns in hour angle has been traced to flexure in the central section carrying the 40-inch concave mirror. The addition of cross-braces has so reduced the drift that it no longer interferes with the observations. The driving and operating mechanism of the instrument performs extremely well.

Comparatively little use has been made of the 20-foot interferometer during the year, since observations can be carried on to better advantage with the larger independent instrument, and the additional time thus made available with the 100-inch telescope has been of great value for other researches.

STELLAR SPECTROSCOPY

A small spectrograph of short focal length almost identical with that which has been used so successfully in photographing the spectra of nebulæ and faint stars has been completed during the year. It may be attached directly to the plateholder frame at the Cassegrainian focus of either the 60-inch or the 100-inch reflector. A second instrument of this type will be of especial value since nebular observations extending over consecutive nights often require the exclusive use of the original spectrograph for long periods of time.

A new two-component lens of ultra-violet glass designed by Dr. Ross, with an aperture of 4 inches and a focal length of 9 feet has been procured for use with the coudé spectrograph. In combination with a prism of ultraviolet glass set for minimum of deviation at the H and K lines, this lens gives good definition over a range of nearly 1000 angstrom units. In this form the spectrograph has been used to photograph in the H and K region the spectra of stars as faint as visual magnitude 5.0 on a linear scale of 6.5 angstroms to the millimeter.

The discovery of bright H and K lines in the spectra of several stars in which they had not been recognised previously and the interesting differences in their behavior have made it most desirable to construct a spectrograph of moderate dispersion well adapted for observations in this part of the spectrum. A three-prism instrument of light flint glass with a camera lens of 15 inches focal length has been designed and will be completed in the instrument shop.

During the year 850 spectrograms have been obtained with the one-prism spectrograph at the Cassegrainian focus of the 60-inch reflector, and 251 spectrograms with the corresponding instrument at the 100-inch telescope. Most of the latter are of faint variable stars. In addition, 125 spectrograms of the brighter stars have been obtained with the high-dispersion spectrograph at the coudé focus of the 100-inch reflector, and numerous other spectrograms with the plane-grating instrument and spectrographs of low dispersion. The members of the staff who have shared in the observations are Adams, Christie, Dunham, Joy, Mayall, Merrill, Sanford and Strömberg. W. P. Hoge has also assisted on some occasions.

RADIAL VELOCITIES

Observations of radial velocity have been continued for many of the stars in Boss's *Preliminary General Catalogue* and for stars in the Selected Areas and in several special lists. The velocities of about 80 stars have been determined from three or more spectrograms. Sanford has nearly completed his program on N-type stars, having measured the velocities of between 60 and 70 objects of this type. The catalogue of the radial velocities of 741 stars by Adams, Joy, Sanford and Strömberg, to which reference was made in the last annual report, has been published during the year.

Special studies have been made by Joy, Sanford and Christie of the velocity curves of a considerable number of variable stars and spectroscopic binaries. Among eclipsing stars investigated by Joy are X Trianguli and RT Sculptoris, the results for which have been published by Dr. Dugan in connection with his photometric observations; W Ursæ Minoris and RT Lacertæ, for which the orbits of the principal stars have been determined; U Sagittæ, a system in which the absolute dimensions of the stars have been derived through combination with the photometric solution of Fetlaar; and TT Aurigæ, for which Joy and Dr. Sitterly have calculated an orbit based on spectrographic observations and the photometric results obtained at Princeton in 1910–11, and have derived absolute masses and dimensions. In the case of TT Aurigæ the spectra of both components are of type B3 and show faint H and K lines, well separated at times of maximum velocity displacement from the interstellar lines of calcium which are also present.

Two other important eclipsing stars investigated by Joy are RS Canum Venaticorum and U Sagittæ. Spectrographic orbits have been derived for both components of RS Canum Venaticorum, but the masses found, each about 1.7 times that of the sun, do not agree well with Eddington's mass-luminosity relationship. The spectroscopic criteria indicate that both stars are dwarfs; but the secondary star of considerably later spectral type must be large enough to produce a total eclipse of the brighter star lasting 4.7 hours.

For the system of U Sagittæ, Joy has found a variable photometric period, the residuals for times of observed minima being reduced considerably by the addition to the mean elements of a sine term with a period of

17 years. Between eclipses the spectrum of only the brighter component could be observed. The star is of spectral type B9 and gives out 93 per cent of the light of the whole system. It was studied for rotational effects during the partial phases when the disk of the secondary star passed in front of it. The secondary is larger and fainter than the primary, has the spectral type G2, and can be observed only during the total eclipse of 100 minutes. Observations made during this interval are sufficient to determine the slope of the velocity curve and hence to give the relative masses of the two stars. This new method of deriving masses in cases in which one component is much fainter than the other may be applied to several other eclipsing stars.

Sanford has determined the radial velocity curves of the Cepheid variables U Aquilæ and DT Cygni and finds the usual close similarity to the inverted light curve. The form of the velocity curve of U Aquilæ would correspond to an orbital eccentricity of 0.40, and that of DT Cygni to a circular orbit. The spectroscopic binaries, Boss 5575 and Boss 5846, each of which shows the spectra of two components, require but a few more observations for completion, and work is well advanced on several other binaries.

Among other stars under investigation by Sanford are the variables U Monocerotis, AC Herculis and V Ursæ Minoris, with periods intermediate between those of Cepheids and long-period variables; U Cygni and R Leporis, of spectral types R and N, respectively; the eclipsing variable UU Cassiopeiæ; and the cluster-type variable RR Lyræ, which has been observed over the phase of rapidly decreasing radial velocity. A comparison by Sanford of the Mount Wilson observations of R Lyræ with those of the Lick and Allegheny Observatories indicates an agreement in phase provided a period is used which oscillates through 13 days in 133 periods about a mean period of 43.48 days. Other variations are present, however, which occur in other periods or are erratic.

The following six stars have been under investigation by Christie: Boss 9 (5 Ceti); Boss 4678 (c Serpentis); H.D. 198287–8; Boss 2824; Boss 4351; and Boss 4971 (λ Ursæ Minoris). Approximate periods have been derived for the first three of these stars, but additional observations will be required for the remainder. H.D. 198287–8 appears to have both a variable velocity for the center of mass and a variable amplitude, the latter in a period of some eight years.

Sanford has secured observations of α Orionis, ζ Geminorum and 19 Piscium with the 9-foot coudé spectrograph. The spectrograms of 19 Piscium will provide accurate wave-lengths for several hundred lines between λ 4700 and *Hα* in this N-type spectrum. Joy has continued his observations of Cepheids and short-period variables and has obtained sufficient material to determine approximate velocity curves for 10 stars. Although the dispersion employed is low (about 75 angstroms to the millimeter at *Hγ*), the changes in velocity are well shown and the residuals are comparatively small. Observations have also been made on variable stars with periods between 50 and 150 days, including M-type variables without bright lines and stars of the RV Tauri type.

A study of the long-period eclipsing variable ε Aurigæ by Adams and Sanford, based on photographs taken with the coudé spectrograph, gives clear evidence of the presence of double lines throughout the spectrum during November 1929–February 1930. A spectrogram of December 1928 when the star was probably at minimum of light showed the lines wide but not double, with the possible exception of the hydrogen lines. Measures of both components were made on the later photographs, which show a relative velocity of 39 km./sec. The D lines of sodium are extraordinarily strong and the bright component of *Hα* is displaced about one angstrom toward the red.

LONG-PERIOD VARIABLE STARS

Merrill and Miss Burwell have made an extensive investigation of the displacements and changes in relative intensity of the bright lines in the spectra of ten long-period variables of type Me and three of type Se throughout the light-cycle. The principal lines used were *Hδ*, *Hγ*, *Hβ*, *Fe* 4202, *Fe* 4308 and *Mg* 4571. The intensity ratio *Hγ*:*Hδ* in Me stars was found to show striking variations, a typical form of behavior being as follows: at phase −0.2, or one-fifth of the period before maximum, the ratio is 0.1; it rises rapidly to 0.5 at phase −0.05, remains nearly constant to phase +0.2, then rises rapidly to 2.5 at about phase +0.4. In stars of type Se the ratio has a minimum of 2.5 at phase +0.07, with higher values earlier and later. In general *Hβ* grows relatively stronger after maximum in Me stars, and in Se stars it is very intense, the ratio *Hβ*:*Hγ* being high at early and late phases, with a minimum after maximum of light. The intensity ratios λ 4308:λ 4202 and λ 4571:λ 4308 have also been studied in detail.

The variation with phase of the apparent velocities derived from the bright lines in the blue and violet part of the spectrum has been determined for 11 stars. Algebraically decreasing velocity at and shortly after light-maximum and a flat minimum 30 to 80 days after light-maximum are typical features. The range in apparent velocity averages about 10 km./sec., probably being larger for the stars with the shorter periods. The phenomena appear to be essentially the same for Me and Se variables. The mean displacement of the bright *Hα* line relative to the blue-violet bright lines is −0.34 A for three stars of type Me and −0.04 A for two stars of type Se.

The mean wave-lengths of 58 bright lines have been determined by Merrill and Miss Burwell in the course of this investigation. The elements identified include *H*, *Fe* I, *Fe* II (both permitted and forbidden lines), *Mg* I, *Si* I, *Mn* I, *Sr* II?, and *In* I?. The forbidden iron lines and an ultra-violet magnesium triplet had not been noted previously in these spectra. Among several unidentified lines, λ 3852.6 and λ 4372.6 are especially prominent. Numerous data for individual stars have been recorded, including wave-length measurements and the phases at which certain lines appear.

The intensities of the bright lines in these stars are not at all the same at equal magnitudes before and after maximum of light, and in general the bright lines behave as if they had little direct dependence on the photosphere. This fact among others may serve to guide the development of a theory of long-period variables. One suggestion is that in these objects various spectroscopic phenomena are not closely interrelated but may proceed in partial independence of each other. The temperature of the photosphere, for example, seems to have no immediate control over the intensities of the bright lines. It appears rather that the brightening of the photosphere is but one of a number of spectroscopic phenomena set in action by a special occurrence at a certain phase—possibly a release of energy at a particular level just before minimum of light.

The existence of titanium oxide above the level at which the bright lines are produced is suggested as a working hypothesis to explain the abnormally low intensities of $H\alpha$, $H\beta$ and $H\gamma$ as compared with $H\delta$. The fraction of total band-absorption to which the bright lines are subject may be greatest at the first appearance of the lines after minimum and decreases as the phase advances.

B-TYPE STARS WITH EMISSION LINES

In continuation of his studies of B-type stars with bright lines Merrill has collected and prepared for publication descriptions of the spectra of 10 such stars showing variations in the intensity and structure of these lines and other features of interest. Observations of μ Centauri made in the course of this survey in 1929 and 1930 show the bright hydrogen lines to be stronger than in 1925.

BRIGHT H AND K LINES IN GIANT STARS OF LATE TYPE

Deslandres and others have in past years observed bright H and K lines in some of the brighter stars of advanced spectral type. The number of such stars has been extended to 15 by Adams and Joy, all giant stars mainly of types later than G5. The observations have been made with the coudé spectrograph of the 100-inch telescope and the regular single-prism instrument at the 60-inch. In most cases the H_2 and K_2 emission lines are sharp and well separated by the absorption lines H_3 and K_3. They differ greatly, however, in intensity and symmetry in different stars, and the study of their relationship to absolute magnitude and spectral type should prove of interest. The three-prism spectrograph now under construction in the instrument shop will be used in continuation of this work.

EXCITATION POTENTIAL AS RELATED TO LINE-DISPLACEMENTS

A preliminary study by Sanford and Adams of the iron and titanium lines on high-dispersion spectrograms of several of the brighter stars indicates that the lines of higher excitation potential give larger negative radial velocities than those arising from low excitation levels. The difference seems to depend upon spectral type, being largest for stars of early type and vanishingly small for stars of types K and M. For a given spectral type the effect is more pronounced among the Cepheid variables. The results found, being based upon solar wave-lengths, are differential with reference to the sun. They are similar in character to those observed by St. John in his study of the outflow in sun-spots.

SPECTRAL CLASSIFICATION OF FAINT STARS IN THE SELECTED AREAS

The program of classifying the spectral types of all stars down to the twelfth photographic magnitude has practically been completed by Humason during the year. Of the 115 areas to be investigated, 112 have been observed. The observation of 23 areas during the year has been made possible through the assistance of Mayall, who photographed 10 areas with the 60-inch telescope. The investigation will be completed as soon as the remaining three areas are within reach of observation.

STELLAR SPECTROPHOTOMETRY

The photographic problems encountered in the measurement of line-contours in stellar and solar spectra have been investigated by Dunham during the past year. A special sensitometer has been built for the purpose of photographing monochromatic standards on each stellar and solar negative. A uniformly illuminated raster, or plate with a series of openings of graduated sizes, is focused by means of a cylindrical lens on the widened slit of a plane-grating spectrograph. When the iron arc is used as the source of light, 12 small squares appear on the photographic plate for every line in the iron spectrum, and the intensity of the light producing each square is proportional to the corresponding opening in the raster. Thus the photographic reduction curve can be drawn at different wave-lengths. Fifty stellar spectrograms standardized by this method have been taken with the coudé spectrograph.

The machine work on the new photoelectric microphotometer has been completed and various recording systems have been investigated by Dunham. A comparison has been made between the string electrometer and a short-period Moll galvanometer with an amplifier. The latter is very promising in its results, and the possibility of tracing the contours of absorption lines directly in the solar spectrum is now being studied.

SPECTROSCOPIC DETERMINATIONS OF ABSOLUTE MAGNITUDE AND PARALLAX

The classification of stellar spectra has been continued regularly throughout the year by Adams and Humason, and the derivation of absolute magnitudes from the spectroscopic criteria has been completed for much of the material. Most of the stars observed have been giants of advanced spectral type.

The revision of the reduction tables for dwarf stars of types F to K8 to provide for the inclusion of additional lines has been completed, and the results have been applied to about 1500 stars for which spectrograms are available. The small corrections to the original reduction system were based upon about 150 stars in Schlesinger's *General Catalogue of Stellar Parallaxes* for which excellent trigonometric parallaxes have been determined. A comparison of the absolute magnitudes derived from these revised tables for all the stars common to Schlesinger's *Catalogue* is shown in the table on page 172.

There are 27 additional stars for which the absolute trigonometric parallaxes are negative. The average difference without regard to sign between the spectroscopic and the trigonometric absolute magnitudes is 0.78 mag., a value which would be reduced greatly by the omission of a few large discordances.

The absolute parallax of the Taurus group derived from 35 stars of spectral types ranging from A7 to K4 and with absolute magnitudes calculated on this system is +0.″023.

Reduction tables for giant stars of types A to K5 have also been completed and the computation of the absolute magnitudes has made good progress. About 2000 stars will be included between these limits of spectrum.

Spectral type	Number	Difference in M (Spec. − Trig.)
≦F2	54	−0 06
F3–F5	100	−0.09
F6–F9	87	−0.12
G0–G2	91	+0.05
G3–G5	51	+0.06
G6–K0	86	−0.10
K1–K4	47	+0 13
K5	34	−0 04
K8	30	+0.06
	580	−0.03

LUMINOSITY DISTRIBUTION AMONG STARS OF TYPES K AND M

Strömberg has succeeded in developing a method by which the distribution of absolute magnitudes can be derived numerically from the distributions of angular peculiar motions and radial velocities. The unknown distribution is determined by the numerical solution of an integral equation involving the three distributions. The method has been applied to the K and M stars of apparent magnitude brighter than 6.0.

Among stars of spectral type K0 to K2 the absolute magnitude distribution shows four maxima occurring at absolute magnitudes −1.8, +0.2, +2.9 and +6.7, with the stars distributed in the proportions of 9, 78, 12 and 1 per cent, respectively. The stars in the four groups have been designated by the terms "supergiants," "ordinary giants," "sub-giants" and "dwarfs." In the spectral interval K3 to K9 three frequency maxima occur at −2.4, −0.1, and between +4 and +9, with relative proportions of 19, 78 and 3 per cent. No sub-giants are found in this spectral interval. Among the M stars, within the range of apparent magnitude used, only supergiants and ordinary giants appear, the frequency maxima occurring at −1.6 and −0.1.

The result for the M stars, and to some extent for the K3 to K9 stars, is somewhat uncertain, due mainly to the relatively small amount of material available. To increase the data a similar method has been devised for the parallactic motions, although the analysis is much more complicated since these motions depend on position in the sky. The parallactic motions of the M stars brighter than apparent magnitude 6.0 have been analyzed according to this method. The results give an absolute magnitude of −4.5 for the supergiants and −0.2 for the ordinary giants, the relative proportions being 9 and 91 per cent.

LABORATORY INVESTIGATIONS

RARE-EARTH SPECTRA

The study of the spectra of rare-earths has been continued during the year by King; 2268 lines for europium, gadolinium, terbium, dysprosium and holmium from λ 3850 to λ 4700, a region especially useful for comparison with stellar spectra, have been classified. Wave-lengths of many of the lines have been measured.

The lines of the ionized atom in each spectrum were first selected by comparing furnace, arc and spark spectra. The enhanced lines are strong in the arc as well as in the spark, but the inclusion of furnace spectra gives a clear distinction between neutral and ionized lines. This was confirmed by the extinction of the ionized lines when cæsium, an element of low ionization potential, was used to furnish a large supply of free electrons, thus causing the ionized rare-earth atoms to return to the neutral state.

The temperature classification was made by comparing furnace spectra at three or more temperatures between 2000° and 2800° C. The varying response to temperature changes showed the relative energy-levels and revealed many furnace lines, often strong, not previously identified in the arc spectrum. The measurements from iron standards of these and of numerous close doublets not previously resolved, together with other prominent lines for which good wave-lengths were essential, resulted in approximately 800 new wave-lengths. A preliminary comparison of these with the wave-lengths of the solar spectrum showed a close agreement between rare-earth lines and many faint unidentified solar lines. This result promises a material extension of the identification of solar lines when more wave-lengths of high accuracy are available for the stronger rare-earth lines.

The phenomenon of hyperfine structure, in which a line consists, under all conditions of excitation, of several components, with definite variations in their spacing and intensity gradation, has previously been noted by King as occurring for rare earths of odd atomic number. This structure prevails for a large proportion of the lines of the odd-numbered elements europium, terbium and holmium. Very few europium lines are quite sharp, while holmium shows broad patterns containing up to eight components. This feature of spectral lines, ascribed to the effect of nuclear spin, is a recent development in spectroscopy. It is receiving much attention on the theoretical side and is expected to form a useful basis of term analysis. The details of such structure must be studied with high dispersion, and during the summer of 1929 Professor R. C. Gibbs and Dr. C. W. Gartlein of Cornell University spent two months in photographing the complex lines of praseodymium with the large spectrographs in the Pasadena laboratory and on Mount Wilson as a supplement to previous high-dispersion work by King and H. E. White. This material furnishes excellent data for the praseodymium spectrum, probably the richest in hyperfine structure of all elements.

Over 4500 lines between λ 2800 and λ 7000 in the spectra of neodymium and samarium have been listed by King as strong enough to use in the temperature classification. Measurement has been necessary for about 25 per cent of the list, as the number of neutral lines previously unidentified is very large, and improved wave-lengths are needed for the prominent lines in general. Spectrograms to supplement the previous collection have been taken, the selection of ionized lines and about half of the temperature classification have been completed, and material has already been furnished to other observers for identification of lines in the solar and flash spectra. The work remaining is chiefly in the red end of these spectra. A further problem in the treatment of neodymium and samarium is the selection of lines occurring in both spectra which may belong to illinium, the element intermediate in the atomic sequence and likely to occur as an impurity. A list of such lines in the yellow and red noted by Kiess and confirmed for the most part by King forms as yet the only data for the probable spectrum of illinium.

An important addition to the high-current equipment of the laboratory, of especial value in investigations with the electric furnace, is a potential regulator with auxiliary transformer. This gives close voltage control of the 100-KW transformer used for the furnaces and adds materially to the ease with which the desired temperatures may be obtained.

THE SPECTRUM OF COLUMBIUM

The spectrograms of columbium previously made by King and already studied with respect to neutral and ionized lines showed that better wavelengths throughout the spectrum are needed before the term analysis can be carried out. These are being determined in cooperation with Dr. Meggers of the Bureau of Standards. About forty arc and spark spectrograms from λ 2600 to λ 7000 with iron-arc comparison have been made for measurement by King. Lines having hyperfine structure with a variety of patterns were found to be very numerous, and a study under high dispersion which has been planned should add materially to the data for this phenomenon and aid in the grouping of lines for series analysis.

THE CARBON ISOTOPE OF MASS 13

Proof of the existence of an isotope of carbon, obtained by King and Professor R. T. Birge from the furnace spectrum of carbon, was noted in last year's report. Further experimental work by King resulted in much better spectrograms of the isotope band λ 4744.5, due to the molecule $C^{13}C^{12}$, on which the spacing of the head and 15 component lines from corresponding lines of the primary band λ 4737 ($C^{12}C^{12}$) could be measured. In addition, an isotope band $C^{13}C^{12}$ at λ 4394.5, belonging to the $C^{12}C^{12}$ band at λ 4382, and one at λ 3595.7, due to $C^{13}N^{14}$ and adjacent to the $C^{12}N^{14}$ band at λ 3590, were found on the later spectrograms. These results, together with previous observations of isotope companions of the cyanogen band λ 3883 and of the carbon monoxide bands in the ultra-violet, give five band systems of carbon or its compounds which are accompanied by isotope bands involving C^{13}.

After the bands had been measured by both King and Birge, the application of the quantum theory of band spectra by Birge showed that the spacing of each of these isotope bands from its primary agrees within a small fraction of one per cent with the values predicted from the presence of C^{13}. Further, the measurements indicate that the mass ratio of the two carbon isotopes is 12 to 13, accurate to about one part in 10,000. Incidentally, the results settle the old controversy as to the emitters of the "Swan" and "cyanogen" band systems, which, as shown by the quantitative evidence from the existence of C^{13}, are due to the diatomic molecules C_2 and CN, respectively. Attempts to estimate the abundance of the new isotope are complicated by an apparent dependence on the method of excitation. With the exception of the very strong band λ 3883, the isotope bands are absent from the arc, although they show distinctly in the furnace and in other low temperature sources. The explanation of this and the derivation of improved constants for the carbon band structure which may be found with the aid of the isotope bands are objects for further study.

On the astrophysical side, the discovery of C^{13} identifies the rather strong band at λ 4744.5, which has been observed during the last 30 years in N-type or "carbon" stars, as due to $C^{13}C^{12}$. It is highly probable that a fainter band at λ 4752, thus far found only in these stars, originates in the molecule $C^{13}C^{13}$. The band at λ 4744.5 has also been observed in cometary spectra at the Lick Observatory.

EXPERIMENTS RELATING TO ELECTRICALLY EXPLODED WIRES

Before much further progress can be made in the study of electrically exploded wires, it will be necessary to obtain definite information concerning the transition of the wire from the liquid to the gaseous state. In an ordinary explosion the time required for the transition is much less than a millionth of a second, and hence the rotating-mirror camera fails to show any of the details of the process. Some work was done by Anderson with the magneto-optic shutter a few years ago (partially published in Mt. Wilson Contribution No. 323) which indicates clearly that the phenomenon is complicated. Since calculation shows that during a part of the short interval magnetic fields of at least a million gauss exist at the surface of the wire, complication might perhaps have been expected. Still, even with this hint it has not been possible to give a satisfactory explanation of the photographs obtained.

The electro-optic shutter, first used by Abraham and Lemoine, and more recently developed by J. W. Beams and others, offers another possibility of studying this problem. With it Lawrence and Dunnington have obtained photographs of sparks with an exposure as short as 4×10^{-8} second, which indicates that if this shutter can be properly controlled it should aid materially in obtaining the data required. During the year experiments with the shutter have been made by Anderson, using first carbon bisulphide in the electric cell, and later nitrobenzene, which has proved more suitable. A reliable method for controlling the exact instants of opening and closing the shutter has not yet been found, and may be difficult to discover; but it should not be impossible.

THE SPECTRUM OF MOLECULAR OXYGEN

In an investigation carried on jointly by Babcock and Professors Birge and Giauque of the University of California at Berkeley, accurate measurements of the faint bands due to the isotopes of oxygen are being used for the determination of the relative masses of the different species of oxygen molecules. This involves a further development of the theory of the isotopic displacement, which is now in progress along with the continued search for other members of the newly discovered system of isotopic bands. On account of the extreme faintness of the bands which are most useful for this purpose, they must be sought with the longest possible air-path and with a spectrograph of unusual capability for recording fine absorption lines. During the prosecution of this search a new band arising from the ordinary molecule $O^{16}O^{16}$ has been discovered and measured. These measurements contribute nothing directly to the investigation of the isotopes O^{17} and O^{18}, but they provide the first precise determination of the vibrational energy of the normal oxygen molecule. At the same time they afford the most accurate standard for comparison with the observations of the Raman effect in oxygen.

Some further work on the structure of the ordinary atmospheric bands of oxygen is now in progress in the laboratory with the interferometer, used with air-paths of 30 meters and less in order to make the lines extremely fine. The results of these measurements will be helpful in the completion of the work on the isotopes.

VACUUM IRON ARC WAVE-LENGTHS

In an investigation of the pressure effect for the spectrum of iron reported a few years ago, it was pointed out by Babcock that reliable values of the wave-lengths of lines from a vacuum arc may now be calculated from the wave-lengths observed for an arc in the open air. A simple computation gives the difference in wave-length corresponding to a change of one atmosphere in the pressure on the source for any iron line whose terms are known. With the completion of an important paper at the Allegheny Observatory on the vacuum iron arc, which gives accurate measures of numerous lines, a reliable comparison has become available, and it is interesting to note that 284 wave-lengths derived by Babcock's method are in excellent agreement with those directly observed. With minor exceptions the differences are within the errors of observation. This satisfactory correspondence is again reflected in the values of the terms for the vacuum iron arc which are now obtained independently by two methods. The means of the terms found directly from the measured wave-lengths and those derived from the open arc by the pressure coefficients are in fact highly reliable. These means furnish the most accurate method at present available for obtaining standards of wave-length in the region λ 1800–λ 3300, where the difficulty of establishing standards by direct measurement is enhanced by the limitations of the interference method. The calculated positions of many of the lines, however, may be used with confidence, since they are subject to uncertainties less than the errors of observation.

THE CLASSIFICATION OF IRON LINES

The correlation between the levels of the spectroscopic terms and the groups to which the associated spectral lines belong has been examined by Babcock for the classifications according to pressure, temperature, dissymmetry and widening. In order to reduce the influence of errors of classification, which are frequently obtrusive, weights proportional to the number of classified lines dependent on each term were assigned. It was found that for each method of classification the levels of the terms increase continuously with increase of the effect, and that upper and lower terms follow parallel courses. For iron such a correlation furnishes a guide for locating the terms corresponding to lines which have been classified but not yet identified as members of multiplets; and it may help by analogy to analyze some other complex spectra.

Every additional means of differentiating the lines of a spectrum is of potential help in finding a physical basis for its peculiarities. For example, an interesting phenomenon has lately been studied in commercial neon tubes having iron terminals, which may assist in further developments. It has been found, in accordance with observations made elsewhere, that when in a vacuum tube containing a noble gas the conditions of pressure become favorable to the sputtering of the electrodes, a spectrum of the metal may be obtained. In the commercial lamps studied the pressure is originally too high for this to occur, but with use the proper value is attained, whereupon an interesting iron spectrum may be observed. Its chief peculiarity is an abnormal distribution of intensity as compared to the ordinary arc spectrum of the metal. The lines of pressure group *d* are markedly intensified relative to those of group *b* in the vacuum tube, as in a source favoring the transitions which involve the highest energy levels in the atom. Contrary to what might be expected in view of this, however, the spectrum of Fe^+ does not appear, and a few lines arising from low atomic levels seem unduly strong. Further study of such spectra, which seem intermediate between those of arc and spark, may aid in improving the classification of the lines and contribute to our knowledge of the structure of the atoms. Numerous lines in these spectra remain unidentified and there are indications that part of these arise from the electrodes and part from the gases in the lamp. This work is particularly suited, in its present phase, to the capabilities of the concave grating of one meter radius which was provided with an Eagle mounting.

RADIOMETERS

Through a plan of cooperation between the Observatory and the California Institute of Technology, Smith has been able to undertake a study of the characteristics of radiometers and has developed an instrument which should furnish very accurate spectral energy curves of the brighter stars. Temperature drift and electrostatic charges have been eliminated as disturbing factors, so that the limit to sensitivity is set solely by Brownian movement. For work on the stars, it was decided to keep the root mean-square of the amplitude of the Brownian motion of the radiometer at 0.05 mm., or less, at one-meter scale distance, thus fixing the uncertainty of the readings at less than 0.1 mm. at one meter.

Control of Brownian movement depends on the proper choice of a suspension. For if A is the force-constant of the suspension and $\delta\theta$ is the root mean-square of the amplitude of the Brownian movement of the radiometer, then $A(\delta\theta)^2$ is equal to the mean energy of a molecule of the surrounding gas. Hence, when one fixes the permissible uncertainty (*i.e.*, $\delta\theta$), a lower limit to the size of the suspension is automatically fixed, independently of the size or shape of the radiometer.

The various factors governing the design of the radiometer itself have been studied, and a satisfactory form of the instrument has been decided upon. One of the instruments was attached to the 60-inch telescope and tested on the spectrum of Arcturus. Some 700 angstroms in the region of *Ha* produced a deflection of 14 mm. at one meter, a degree of sensitivity sufficient for work on all the brighter stars.

Some work has been done on the design of a suitable spectrometer for use with radiometers, but thus far no thoroughly satisfactory design has been produced.

Because the amplitude of the Brownian motion, and hence the uncertainty of readings, is reduced at low temperatures, it was thought worth while to investigate the behavior of radiometers at liquid air temperatures. The sensitivity of a radiometer at the temperature of liquid air was compared with that of the same radiometer at room temperature. Curves were derived for both temperatures which show the change in sensitivity with pressure for the same radiometer in hydrogen, helium and air. In these gases, at the lower temperature, the maximum sensitivity is increased and shifted toward lower pressures. The form of the pressure-sensitivity curve remains unchanged.

A NEW METHOD FOR OBSERVING AND MEASURING SPECTRAL LINES

Anderson has obtained some interesting and perhaps very important results by inserting a cylindrical lens just behind the objective of the microscope used in measuring spectrograms. If the axis of the lens is adjusted at right angles to the spectral lines, the grain of the photographic plate disappears completely as each grain is elongated enormously in a direction parallel to the lines. This makes it possible to use relatively high magnification with a resulting increase in precision of settings.

The experiments were suggested by a recent article in the Zeitschrift für Physik, in which the author, J. Linnick, describes very briefly some results obtained by causing the microscope objective to vibrate rapidly in the direction of the spectral lines. The use of a cylindrical lens to obtain the same results apparently did not occur to Linnick.

The examination of an iron-arc spectrogram taken in the first order of a concave grating of one meter radius leads to the following conclusions:

1. The precision of wave-length measurements is increased probably three-fold by the use of the cylindrical lens.
2. Without the lens, doublets whose separation on the plate is less than 0.020 mm. can not be resolved.
3. With the cylindrical lens, several rather strongly exposed pairs with separations of 0.008 to 0.010 mm. are easily divided, and moderately exposed doublets separated by 0.006 to 0.008 mm. are resolved, thus indicating that the limit of resolution in the region λ 2700–λ 3000 may be about 0.005 mm. The theoretical limit in the same spectral region for this grating, assumed to be a perfect optical instrument, is 0.0045 mm. The photographic plate was an Eastman Par-Speed Portrait film.
4. Very faint lines are much easier to see and to measure with the aid of the cylindrical lens.

Preliminary trials indicate that the method can be employed with similar success on absorption spectra.

A NEW MICROPHOTOMETER

Smith has designed a very simple registering microphotometer which uses a short-period radiometer as the light-sensitive element. The usual complicated gearing is avoided by the use of two telechron clock motors, one driving the plate and the other the recording mechanism. Records are made on double width motion-picture film. Such an instrument in a temporary form has been tested with excellent results.

AN IMPROVED FORM OF TEMPERATURE REGULATOR

A sensitive temperature regulator which has proved to be very efficient and stable has been built by Smith for the fixed coudé spectrographs used with the 100-inch telescope. The vapor pressure of ether in a bulb at one end of a closed U-tube of glass regulates the height of a column of mercury which makes contact with a tungsten wire. Contact is broken in an atmosphere of hydrogen which prevents fouling of the point of contact. Several tungsten wires are sealed into the tube to provide for coarse adjustment, and fine adjustment is secured by tilting the U-tube on its supporting frame.

THE RULING MACHINE

Considerable improvement in the performance of the ruling machine and the maintenance of its adjustment has resulted from the reconstruction of the diamond carriage and a number of minor changes. In recent months the machine has ruled four 4-inch gratings and one 3-inch of excellent quality. Two 8-inch gratings with long lines, one of which is plane and the other concave, with a radius of 30 feet, are somewhat less satisfactory, although both will be of value until the time when it becomes possible to make such large gratings of the finest quality. In the case of all these gratings the diamond points have been shaped to throw an exceptional amount of light into certain specified orders and the results have been most successful.

Babcock has devoted much time to the general supervision of the ruling machine and together with Jacomini has made studies of various features of the machine and numerous tests of the rulings. The design for a smaller machine incorporating the results of experience with the larger engine has been completed by Jacomini and Pease.

THE VELOCITY OF LIGHT

The decision made by Dr. Michelson last year to use a pipe-line exhausted of air for his further measurements of the velocity of light led to immediate preparations to assemble the necessary equipment. Through the kindness of Mr. James Irvine jr. the use of an excellent site was secured on the property of the Irvine Ranch about six miles southwest of the city of Santa Ana. The land is remarkably level, varying only a few feet in elevation over a distance of one mile.

A contract was made with the California Corrugated Culvert Company to furnish the 36-inch corrugated steel pipe in lengths of approximately 60 feet. The design of the air-tight connections at the joints, the heavy steel cylinders enclosing the optical parts, the mirror supports and slow-motion controls, the pump connections, and many other parts of the equipment is due mainly to Nichols of our engineering department.

During the autumn months a section of the pipe-line 1140 feet long was set in position and the complete apparatus was installed and tested by Pease and Pearson. A small Kinney pump with a capacity of 100 cubic feet a minute exhausted the air to a pressure of about 15 mm. of mercury. After the mirrors had been adjusted and the rotating mirror set in motion, it was found that ample light was available after three reflections from each end, even when an ordinary arc lamp was used as the source of light. With five reflections, however, the return image was faint and a much more powerful arc lamp of special design was installed which overcame this difficulty.

The complete pipe-line, one mile in length, was set up during the spring months and the optical system was transferred to this longer distance. After the joints had been carefully examined for leaks and covered with a rubber paint the small pump was attached to the full length of pipe. After operation of the pump for 51 hours the pressure was reduced to 18 mm. and maintained at this value without difficulty. An additional pump, however, with a capacity of 350 cubic feet a minute has been purchased to provide for evacuation within a shorter time. Good return images have been obtained after three reflections, corresponding to a total light-path of 6 miles, and there seems to be little question that the full distance of 10 miles can be used in accordance with Dr. Michelson's original plans.

The funds for this investigation have been provided by the Rockefeller Foundation and the Carnegie Corporation of New York, and the research is being carried on jointly by the Observatory and the University of Chicago.

CONSTRUCTION DIVISION

ENGINEERING AND DESIGN

The general design of instruments and apparatus used in the work of the Observatory has been in charge of Nichols, and H. S. Kinney has made most of the detailed drawings for the instrument shop. Pease has given considerable attention to certain special pieces of apparatus, in particular the design of the new ruling machine and the support system for the 100-inch mirror.

Among the more important instruments designed in this department in the course of the year, in addition to those already referred to, are: a photoelectric and a radiometric microphotometer; the new low-dispersion Cassegrainian spectrograph; the three-prism spectrograph for work in the violet; a plate-testing photometer; a plane-grating spectrograph for photometric standardization; the "Schraffierkassette" for photometric work; the apparatus for the measurement of lunar radiation with the thermocouples; and several instruments for the eclipse expedition. A design has been completed for the cooling system on the large solenoid magnet in the physical laboratory. Much work has been done on minor apparatus, on drawings for the Observatory publications and for the material sent to the Annual Exhibit of the Carnegie Institution.

THE INSTRUMENT SHOP

Alden F. Ayers has remained in charge of the instrument shop, which has built many pieces of apparatus during the year. The completion and adjustment of the 50-foot interferometer have required considerable work both in the shop and in the field, and a similar statement applies to the equipment for the measurement of the velocity of light at the Irvine Ranch.

In addition to giving time to repairs and the maintenance of equipment, the instrument shop has partially or wholly completed the following instruments and apparatus: the photoelectric microphotometer; the vacuum spectrograph; three spectrohelioscopes; a plate-testing photometer; the low-dispersion short-focus spectrograph; the radiometric microphotometer; a plane-grating spectrograph; the Schraffierkassette; instruments for the Solar Laboratory and the eclipse expedition; the cooling coil for the solenoid magnet; and the support system for the 100-inch mirror.

L. R. Hitchcock has continued to act as instrument maker at the Solar Laboratory and has assisted Dr. Hale in many of his solar observations.

THE OPTICAL SHOP

In the optical shop W. L. Kinney and Dalton have carried on a wide variety of work. Kinney has figured to a spherical form two fused silica disks, one 11 inches and the other 22 inches in diameter, in connection with experimental tests relating to the 200-inch telescope. The larger of these has been examined under extreme conditions of temperature for changes of figure and other possible modifications. Kinney has also figured a 5-inch prism for the Cassegrainian spectrograph; 3 light-flint prisms for the ultraviolet spectrograph; a 12-inch objective prism for the photographic refractor; and a 7-inch prism of ultra-violet glass for the coudé spectrograph. The difficult task of working to an optical figure the inside and outside surfaces of the fused quartz tube used by Dr. Abbot in his radiometric investigations was also carried out successfully by Kinney.

Dalton has given much time to figuring plane and concave speculum plates of 1 to 10 inches diameter for use as grating blanks for the ruling machine. He has also made from glass and quartz a large number of lenses up to 4 inches in diameter, plane mirrors up to 10 inches and small prisms of various angles. Included among the prisms are two of the Wollaston type of crystalline quartz. Dalton has carried on much miscellaneous optical work, including the refiguring and recementing of two large Nicol prisms, the grinding and polishing of several pairs of stellite slit-jaws, and the figuring of disks of calcite for radiometer mirrors less than 0.001 inch in thickness.

M. H. Brown has completed in our shop the optical parts for two 12-inch telescopes of the Cassegrainian type for use in the investigation of sites for the 200-inch telescope.

CONSTRUCTION, MAINTENANCE AND OPERATION

Owing to the illness of George D. Jones, superintendent of construction for many years, who has been on leave of absence during a part of the year, maintenance and construction work has been under the charge of A. N. Beebe.

A new conduit line with circuits to provide alternating current in the domes of the large reflectors and in some other buildings represents the chief construction on Mount Wilson during the year. A steel storage tank for fuel distillate has been installed recently to replace the underground concrete tank in use for many years which had developed a serious leak. The painting of the exterior of all the steel buildings with aluminum paint has been completed, and improvements have been made in the roadways and the fire-breaks along the summit of the mountain.

There has been no new construction in connection with the buildings in Pasadena, but general repairs have been maintained as usual.

Merritt Dowd, engineer, and Sidney Jones, assistant engineer, have continued in charge of the operating plant on Mount Wilson. The two storage batteries, one of which was installed in 1906 and the other in 1909, and which, due to the efficient care of Dowd, have been in continuous service for over 20 years, were finally replaced in April of this year. The new batteries, each consisting of 55 cells, have a total capacity of 500 ampere-hours on an 8-hour discharge rate.

The third consecutive season of seriously deficient precipitation finds the water supply of the Observatory still fully adequate for its needs. There have been no forest fires of consequence in the vicinity of Mount Wilson during the year, and the probable danger from this source is growing less as the efficiency of the system for patrolling the forest area increases. As in previous years the Observatory has cooperated with the Forest Service and the Pasadena and Mount Wilson Toll Road Company in maintaining a patrolman on the summit of the mountain.

THE LIBRARY

On June 30, 1930, the bound volumes in the library numbered 10,704; the number of pamphlets was about 7500 and of lantern slides about 2500. Between July 1, 1929, and June 30, 1930, the library acquired 390 bound volumes, 112 by purchase, 255 by binding, and 23 by gift. During 1930, 118 periodicals and transactions of learned societies have been received, of which 34 are gifts or exchanges. In addition, the publications of about 200 observatories and research institutions are received at more or less frequent intervals.

NUTRITION LABORATORY[1]

FRANCIS G. BENEDICT, DIRECTOR

The unusually close international relationships that have existed between the Nutrition Laboratory and research institutions in European countries were further strengthened this year when nearly two thousand scientists came to Boston for the meetings of the XIIIth International Physiological Congress, in August 1929. A large proportion of the members of the Congress visited the Nutrition Laboratory at least once to view the special exhibits and demonstrations prepared for them, and it was a prime event in the life of the Laboratory to greet in our own building so many of our friends from outside the United States. The Carnegie Institution of Washington invited several score of the visitors to a series of special luncheons held at the Nutrition Laboratory, and the spirit of international friendship and accord was seen on every hand. A few of the Congress visitors remained after the meetings, to study the work of the Laboratory further, and the correspondence since the close of the Congress has shown an unexpected enthusiasm and appreciation for the work of the Carnegie Institution of Washington as a whole and that of the Nutrition Laboratory in particular.

The intimate connection of representatives from so many nations, all bent upon the furtherance of knowledge in the biological sciences, served as a great impulse to better international understandings. In no field of human endeavor is there any greater spirit of idealism and absence of commercial interests than in the biological sciences. There may be a chemistry for one country, an engineering for another, but there is no medicine, no physiology, and no pathology except for the world as a whole. On this common ground of idealism in service to mankind these two thousand scientists and friends gathered together for a week in Boston (the first meeting in the United States) to renew old friendships, establish new contacts, and present the results of their discoveries to all the world. The small share of the Nutrition Laboratory in this great event supplemented admirably the lecture tours of former years and led us to hope that the spirit of international friendship and accord among scientific men, so well advanced by Captain J. P. Ault and the cruise of the *Carnegie*, was in some measure furthered as a result of the Nutrition Laboratory's activities, which were inspired in no small part by Captain Ault's work.

Since its establishment in 1907, the Nutrition Laboratory has continually endeavored to promote friendly international relations with the numerous European centers of research. Through the lecture tours, the personal visits of members of the Nutrition Laboratory staff to European laboratories, the reception as guests of a number of foreign visitors, and the residence in Boston of Rockefeller associates from abroad, European laboratories have been brought into especially close touch with our work. In recent years the development of a comprehensive plan for studying the metabolism of peoples of various races has brought us into contact with Orientals and other races, especially in China, Japan, Australia, New

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[1] Situated in Boston, Massachusetts.

Guinea, India, and Hawaii, thus giving the Nutrition Laboratory an unusually active relationship with scientists all over the world. That these relationships are not merely friendly but are based upon a common desire for furtherance of scientific knowledge is shown by the fact that the Nutrition Laboratory is actually engaged in cooperative investigations with a large number of research centers in different parts of the world.

COOPERATING AND VISITING INVESTIGATORS

Professor E. G. Ritzman, of the Laboratory for Animal Nutrition at the University of New Hampshire, has continued his active studies on the metabolism of sheep, employing the extensive equipment installed at Durham. As in former years, this cooperative research has been most successful, with an experimental, editorial, and financial division of labor that is unique in cooperative investigations, due in large part to the sympathetic support of Director John C. Kendall of the Agricultural Experiment Station and President E. M. Lewis of the University of New Hampshire. The laboratory at Durham has become a Mecca for many students interested in agricultural research and particularly in animal nutrition. Indeed, a number of the members of the XIIIth International Physiological Congress visited Durham and spent several days there.

Professor Lafayette B. Mendel, of Yale University, has devoted considerable time to the cooperative research with this Laboratory in the study of the metabolism of the albino rat. Two articles are now in press (see page 192) and the investigation is proceeding with unusual smoothness.

Dr. Oscar Riddle, of the Department of Genetics of the Carnegie Institution, has intensively continued his cooperation in the study of the metabolism of pigeons and doves, has supervised the installation of a second multiple-chamber respiration apparatus, and has prepared a report upon the differential sex reaction of these birds to changes in temperature. Thanks to the hearty and sympathetic support of Director Charles B. Davenport, an elaborate and most successful cooling system for the respiration apparatus has been provided and installed, enabling studies at widely varying environmental temperatures.

Professor Josef M. Petřík, of the Department of Physiology of Masaryk University at Brno, Czechoslovakia, has spent several months at the Nutrition Laboratory as a visiting Fellow of the Rockefeller Foundation. As is the case with most of these visiting Fellows, the major part of his time was devoted to a general survey of the Nutrition Laboratory's methods and problems, but Professor Petřík also cooperated in a most interesting study of the metabolism of the wild rat.

A conference of those interested in the biological phases of the Carnegie Institution's work was held at the Nutrition Laboratory on May 17, 1930. Those present were President J. C. Merriam, Mr. W. M. Gilbert, Dr. G. L. Streeter, Dr. Oscar Riddle, Dr. D. H. Tennent, Dr. C. B. Davenport, Dr. T. M. Carpenter, and Dr. F. G. Benedict. This conference and others like it are cementing in an extraordinary way the numerous biological interests of the Institution and giving excellent opportunity for studying, first hand, the equipment and the major problems of the various institutions visited.

Through the long-established friendship between Professor M. Schaternikoff of Moscow and this Laboratory, Professor M. F. Tomme of the Zootechnical Institute at Moscow was received as a guest at the Nutrition Laboratory and spent his time studying especially our problems of direct calorimetry and the unusual equipment for investigating the metabolism of farm animals at Durham, New Hampshire, under the supervision of Professor Ritzman.

Dr. Alexander J. Szarka, of the Laboratory of Professor Fr. Verzár at the University of Debreczen, Hungary, visited the Nutrition Laboratory while en route to California, where he is to spend some time with Professor H. M. Evans. Dr. Szarka arrived at the time of our active study of the metabolism of wild rats, in association with Professor Petřík, and hence had a favorable opportunity for studying our special technique for measuring the rat's metabolism.

Miss Theodora Nussmann, of the University of Cincinnati, spent a week at the Laboratory likewise acquiring our technique for studying the metabolism of rats, preparatory to going to the Department of Genetics to act as an assistant in the cooperative research with Dr. Oscar Riddle on pigeons and doves.

Mr. B. L. Bennett, of the Department of Tropical Medicine of Harvard University, received training at the Laboratory in the use of the "field respiration apparatus" and the general technique of basal metabolism measurements, preparatory to assisting Dr. G. C. Shattuck in a cooperative study with this Laboratory on the metabolism of Mayas in Yucatan. (See page 191.)

In addition to the hundred members of the XIIIth International Physiological Congress who were entertained at luncheon by the Nutrition Laboratory, it is probable that nearly one thousand visited the Laboratory during the week of the Congress. Of these, several returned for a prolonged stay, either in Boston or in Durham. Among those visiting Durham were Professor H. Dryerre of the Royal Dick Veterinary College at Edinburgh, Monsieur J. Alquier of the Société Scientifique d'Hygiène Alimentaire at Paris, Professor J. M. Petřík of Brno, and Professor M. F. Tomme of Moscow.

Dr. E. Simonson of Frankfurt spent considerable time at the Laboratory, studying special techniques.

Among other visiting physiologists from outside the United States, we wish especially to mention Professor L. Lichtwitz of Altona, Germany, and Professor W. A. Osborne, of the University of Melbourne, Australia, with whom most stimulating discussions were had.

The cooperating investigators interested in studies of racial metabolism, with whom we are in constant correspondence and from whom we are in frequent receipt of protocols, are: Professor Eleanor D. Mason, of the Women's Christian College, Madras, India; Professor C. S. Hicks, of the Department of Pathology, University of Adelaide, Adelaide, South Australia; Professor H. S. D. Garven, of Moukden Medical College, Moukden, Manchuria; Professor L. G. Kilborn, of West China Union University, Chengtu, Szechwan, China; and Professor Carey D. Miller, of the Department of Household Science, University of Hawaii, Honolulu. Reports are likewise expected soon from Dr. M. Odin of Umeå, Sweden. We regret to have to record the loss of observations and equipment in the tragic accident to the yacht *Carnegie.*

LECTURES

Dr. T. M. Carpenter lectured as usual at the Harvard Medical School on the general subject of basal metabolism. On December 14, 1929, the Director gave a short address on "Heat production in the human body" at the Carnegie Institution of Washington, in Washington, D. C., and on February 8, 1930, he gave an address before the Twentieth Century Club in Boston on "The proposed re-entry of light wines and beers in American life."

INVESTIGATIONS IN PROGRESS

Gas-analysis apparatus—During the past year, the Carpenter gas-analysis apparatus has been improved by the installation of a mechanical device for the circulation of the potassium-pyrogallate solution, which has resulted in a considerable shortening of the time required for analysis and in much saving of manual labor. The conditions necessary for the daily satisfactory functioning of the apparatus have been determined. The use of a slightly less accurate apparatus is being studied, and the construction of a form for the simultaneous analysis of two samples of gas is well under way. Dr. Carpenter has been aided in the many necessary analyses by R. C. Lee and Miss A. E. Finnerty. The Laboratory is now in possession of four complete gas-analysis apparatus of the Carpenter type that are functioning perfectly. There are likewise three apparatus in constant use at the Laboratory for Animal Nutrition at Durham, New Hampshire.

Respiratory quotient and alveolar air after ingestion of simple sugars—A method for the determination of the alveolar carbon dioxide during the measurement of the respiratory exchange in short periods has been worked out, and this determination is now being used as an indication of the significance of the respiratory quotient after the ingestion of fructose and of glucose. The experiments have been carried out by Dr. Carpenter, with the technical assistance of R. C. Lee, T. J. Farrell, B. Gruber, and A. E. Finnerty.

The gaseous exchange after the ingestion of galactose—The effect upon the respiratory exchange of the ingestion of varying quantities of galactose is being studied by two different methods, with special reference to tolerance and to the possible difference between the sexes. The observations are in charge of Dr. Carpenter, who has been aided by R. C. Lee. The gas analyses have been made by B. Gruber, T. J. Farrell, and A. E. Finnerty.

Tests of absorbents for carbon dioxide—In respiratory studies no one factor is of more general importance than the complete absorption of carbon dioxide. The problem is not so much one of absorption of carbon dioxide from a small sample of gas in a gas-analysis burette but the removal of carbon dioxide from a ventilating air current of fairly large volume. For this purpose various absorbents have been used. There are at least three different types of satisfactory soda-lime on the market. Since the Nutrition Laboratory's use of material of this kind amounts to several hundred pounds in the course of the year, extensive tests are under way to find that absorbent best adapted to our work. Fused caustic soda in a special form called "shell natron" has proved most advantageous in certain apparatus, but we have found that the retention in the absorbing vessel of the water formed by the reaction and the solidification of the mass tend to clog the air current and cause trouble. There is no one ideal absorbent, and thus far each of the various types finds special use. E. L. Fox has been active in carrying out these tests.

A helmet form of respiration apparatus—Frequent reference has been made to the development of this simple type of respiration apparatus, which was demonstrated at the exhibit in Washington in December 1929. To provide an air-tight closure around the neck with not too great constriction and to enable the most normal type of respiration, this apparatus has been developed and is now rapidly replacing the older forms of face mask, mouthpiece, and nose-pieces. This apparatus, particularly in conjunction with the extraordinarily accurate Carpenter gas-analysis apparatus, furnishes an excellent method of attack in studies of respiratory exchange, especially of the respiratory quotient, that is, the ratio between the carbon dioxide eliminated and the oxygen absorbed during respiration. The helmet has been used successfully with almost every type of respiration apparatus that we have, either closed or open circuit. It is not adapted to apparatus employing valves. We believe that the respiratory quotient may now be studied with a degree of accuracy heretofore never attained and with a greater assurance of normality of respiration. The experiments with the helmet have been made with the assistance of E. L. Fox and R. C. Lee.

The oxy-calorimeter—A simple method for determining rapidly and accurately the heat of combustion or the energy value of foods and excreta has been found in the oxy-calorimeter described in previous reports. (See abstracts in Carnegie Inst. Wash. Year Book No. 24, 1925, p. 135; and Year Book No. 25, 1925–26, p. 148.) The accuracy possible with this apparatus was by no means fully appreciated at the start, and but imperfect temperature control was suggested in the published descriptions. The methods of temperature control have been the subject of investigation the past year, and experiments have shown that with special attention to temperature control, great accuracy can be secured.

Insensible perspiration—A simple method of securing an approximation of the total metabolism has been introduced in several clinics. This consists in measuring the insensible perspiration, that is, the invisible loss in body weight occurring continually from minute to minute or from hour to hour, due to the elimination of water vapor and carbon dioxide from the lungs and skin. The successful introduction of this method into the clinic has led to the further control of the technique, and further experiments have been carried out to amplify our earlier work. It is becoming increasingly evident that accurate determinations of the insensible perspiration have a real value in the clinic.

Metabolism of the goose—This rather remarkable laboratory animal, with its capacity for storing indefinite amounts of fat, with its thick insulating covering of feathers, its extraordinary docility, and its ability to withstand fasting indefinitely, is an ideal animal for many types of experiments. Further studies of this animal with reference to prolonged fasting and particularly with reference to its reaction to environmental temperature have been carried out, all of the measurements being made by direct calorimetry. The expense involved in direct calorimetric determinations with humans has made it necessary for us to forego such measurements for many years, but there is a large number of problems with the goose in the solution of which our emission calorimeter may be used with advantage. In addition to the extensive studies on the transformation of carbohydrate to fat by surfeit feeding, a series of observations is in progress dealing with the effect upon the metabolism and the digestive action of the goose of the ingestion of various amounts of food. V. Coropatchinsky has had charge of these experiments, assisted by G. Lee and B. James.

Metabolism of the wild rat—The innumerable measurements on the albino rat give us a perfect picture of the basal metabolism of this valuable laboratory animal, but little is known with regard to its prototype, the wild rat. A number of wild rats were captured in various localities and, for comparison with the albino rat, were studied with regard to their basal metabolism, their reaction to changes in environmental temperature, and their resistance to fasting. This research has been carried out with the active cooperation of Professor J. M. Petřík of Brno, Czechoslovakia.

Relation between the respiratory quotient and the protein disintegration of rats—In the studies of the wild rat seemingly aberrant, high respiratory quotients were noted with the approach of death at the end of fasting. Another investigation was therefore begun with the albino rat to study during prolonged fasting the respiratory quotient and the nitrogen output, in an attempt to correlate the changes in respiratory quotient with any changes in protein disintegration. The observations were made primarily upon the albino rat, but include some upon the wild rat. The measurements of the respiratory exchange have been made by E. L. Fox. The nitrogen analyses have not yet been carried out.

Metabolism during mental effort—The source of intellectual effort and its possible energetic relationships have been the subject of an age-long controversy. As a step towards settling this controversy, a comprehensive study has been made of the metabolism during mental effort. Five men and one woman acted as subjects. The metabolism of each was measured both during muscular and mental repose and while solving mathematical problems in the head, without aid of paper or pencil. Attempts were made to rule out the possible element of excitation or "attention" by measuring the metabolism also during a period of response to an electric buzzer or light. A preliminary report on the research was given before the National Academy of Sciences in April 1930, and has been published in their Proceedings. (See abstract on page 196.) The complete details are at present being elaborated. This investigation was carried out with the cooperation of Mrs. Cornelia Golay Benedict. In this research the helmet respiration apparatus proved highly successful.

Experiments with a hypnotic subject—Normal sleep is commonly considered to cause a depression in metabolism of approximately 10 per cent, and although basal metabolism should, strictly speaking, be the lowest metabolism, it is impracticable to insist upon sleep as a prerequisite for basal metabolism measurements. Hence basal metabolism is, by common consent, considered as being the metabolism of the subject when awake. The various factors making for an increased metabolism, such as digestive activity and mental excitation, are well known but avoided frequently only with difficulty. The factors known to depress metabolism below the so-called "basal" are few, such as drugs and normal sleep. As a contribution to the physiology of hypnosis as well as to the study of basal metabolism, we took advantage of cooperation with Dr. J. C. Whitehorn and Dr. H. Lundholm of the McLean Hospital in Waverley, Massachusetts, to make some observations on two different subjects during deep hypnotic sleep. These observations were carried out in part at the Nutrition Laboratory and in part at the McLean Hospital, the respiration apparatus employed at the Nutrition Laboratory being sent out to the hospital for use there. Most of the observations were in the hands of E. L. Fox.

Metabolism during muscular work—Although the Nutrition Laboratory has been unable to carry out its original ambitious plan for the study of the physiology of exercise, contributions are intermittently made to this important and deeply interesting phase of physiology. With the introduction of the helmet, an improved method of attack was available. Following the preliminary observations of Dr. Fritz Strieck of Würzburg, a resident Rockefeller Fellow at the Nutrition Laboratory for several months in 1928–1929, we continued our observations on the metabolism during muscular work and particularly the after-effect of muscular work. Although the excess oxygen consumed during the first fifteen minutes after a period of severe muscular exercise does not bear as close a relationship to the oxygen consumed during work as we at first thought would be the case, it became possible with the improved technique to secure a great deal of data upon the rapidity and intensity of the recovery processes. This equipment with the closed circuit, furthermore, made it possible to attack experimentally, in a manner heretofore never attained, the problem of the oxygen consumption and the recovery processes when one is breathing oxygen-rich atmospheres. The respiratory quotient during the period of muscular work could be determined even when the atmosphere contained over 80 per cent of oxygen. Graphic records of the oxygen consumed during the recovery period were obtained in all of the experiments. Not only were the measurements made with various atmospheres of oxygen but likewise with air. Furthermore, two entirely independent methods, open- and closed-circuit methods, were compared, employing the helmet and the Carpenter gas-analysis apparatus. The observations were in the skillful hands of R. C. Lee.

Metabolism of sheep—The long experience of Professor E. G. Ritzman in sheep breeding and genetic studies, in cooperation with Dr. Charles B. Davenport, gave special success to our study of the metabolism of this economically important animal. Using several forms of respiration chamber, we have made metabolism measurements on sheep during growth, with special reference to environmental temperature, prolonged fasting, sex, the effect of grouping *en masse*, or huddling, shearing, and castration. These observations have given us data having important bearings on numerous physiological problems. Many of the results have been incorporated in a report now in press. (See page 192.) This work was ably assisted by Miss H. M. Hilton and Messrs. A. D. Littlehale and N. F. Colovos.

Metabolism of pigeons—The unusually successful returns from the cooperative investigation with Dr. Oscar Riddle of the Department of Genetics, in which his extensive colony of doves and pigeons has been used, justified the elaboration of this research and a second multiple-chamber respiration apparatus has been installed and a second assistant engaged, to enable the observations to be carried on at double the former rapidity. Special emphasis has been laid upon the problem of sex and rather remarkable sex differentiations have been noted in the resistance to environmental temperature. The metabolism of the numerous well-defined races of doves and pigeons has been further studied, thus pointing out the significance of racial characteristics and the close bearing of the experiments with these small animals upon our larger study of the racial metabolism of man. In these studies at Cold Spring Harbor we have had the intelligent and skillful cooperation of Miss G. Christman and Miss T. Nussmann.

Metabolism of the albino rat—The special laboratory assigned by Yale University to this cooperative research between the Nutrition Laboratory and Professor Lafayette B. Mendel has been in active operation throughout the past year with the energetic assistance of Miss Kathryn Horst. With the multiple-chamber respiration apparatus, results have accumulated rapidly. Special emphasis has been placed upon the influence of exercise upon the metabolism of rats compared with control, resting animals, these studies being supplemented by an analysis of the bodies of the animals after the metabolism measurements were made. The influence of growth has also been studied, including observations now in progress on a 750-gram male rat. The influence of prolonged fasting has been studied especially with this large animal. The age factor is being studied with rats that are being maintained especially for this purpose. Modifications of the technique making for quieter periods are continually being tested, and slight alterations in technique are accepted as they are proved of worth.

Oxy-calorimeter studies of food wasted in homes, restaurants, and cafeterias—No one problem has been more complicated in dietary studies than the calculation of the food energy lost in ordinary table and kitchen waste. The application of the oxy-calorimeter to this problem has been intensively carried out by A. Gertrude Farr at the New Hampshire Agricultural Experiment Station, with the active support of Director John C. Kendall. In an earlier study of the energy content of foods commonly eaten in a college community, it was noted that the energy value of a mixed diet could be fairly accurately determined by multiplying the air-dry weight (in grams) of a sample of the mixed meal by the factor 5. The oxy-calorimeter has been further employed to note whether the energy value of foods wasted in the home, the restaurant, and the cafeteria can likewise be approximated by the application of a constant to the air-dry weight.

Racial metabolism—No one cooperative investigation engaged in by the Nutrition Laboratory has proved of as general and wide-spread interest as the study of racial metabolism. With a simplified technique especially designed for this purpose, with a number of co-workers practically all of whom received their technique at the Nutrition Laboratory or from individuals who have been trained here, the comparison of results has probably been put upon as sound a basis as possible. Professor Eleanor D. Mason, of the Women's Christian College at Madras, India, has devoted a large proportion of her time to the study of the metabolism of the women of India and is making an extensive contribution to the physiology of this race. The spirometer type of respiration apparatus loaned her by the Nutrition Laboratory has been supplemented by a helmet, to enable a special study of the metabolism during sleep, in order to determine whether the low metabolism normally found with Indian women is still further lowered by sleep. Samples of urine are also being collected, to note the protein katabolism. Professor C. S. Hicks, of the University of Adelaide in South Australia, has furnished us with the protocols of a large number of experiments which are now being elaborated. The difficulty of research with these primitive peoples is hardly possible to conceive. Further studies are eagerly anticipated. In China, in spite of the political unrest, reports are being received regularly from Professor H. S. D. Garven at Moukden, and from Professor L. G. Kilborn at Chengtu, Szechwan. A systematic survey of the basal metabolism of the Chinese in various parts of China is therefore reasonably well assured. In Hawaii, the great melting pot for the various nations, Professor Carey D. Miller, of the University of Hawaii, has continued her studies on the mixed races, extending her observations into some of the outlying islands. This investigation, although only in its inception, promises a great deal for the future. The extraordinary observations made by Dr. G. D. Williams on the Mayas in Yucatan (in which the two outstanding features were the predominantly high metabolism of these Mayas, although in a tropical climate, and the number of instances when the pulse rate was unusually low) have been supplemented by a study in cooperation with Dr. G. C. Shattuck and Mr. B. L. Bennett of Harvard University. The protocols have just been received and at the time of writing are not completely checked. Further research with this most interesting race is contemplated in the near future, in cooperation with the Department of Genetics. With the annual migration of the Lapps to certain centers in Sweden it is hoped that data on their metabolism will be available before long. Dr. M. Odin, of Umeå, Sweden, has been active in securing collaborators to carry on these observations. Supplementing our studies in the field, we have received a great deal of assistance from Professor Abby H. Turner, of Mount Holyoke College, who not only has measured there the metabolism of several women from India but has also been active in securing 24-hour specimens of urine from a number of Indian students subsisting upon an American diet, the object being to study their protein destruction. To aid us in our study of the effect of acclimatization to a different climate (one of the sub-topics which is being developed in connection with our larger racial study), metabolism measurements upon Indian women who have recently left their native country have kindly been made for us by Dr. L. H. Newburgh and Miss M. F. O'Connor of the University Hospital at Ann Arbor, Michigan, by Professor C. C. Benson of the University of Toronto in Canada, and especially by Dr. C. G. L. Wolf of Addenbrooke's Hospital, Cambridge, England.

Installation of apparatus for studying the heart rate—The close correlation between pulse rate and metabolism, noted frequently although not invariably in many of our researches, has made accurate determinations of the pulse rate of great importance. The use of the stethoscope requires the continuous attention of an assistant. The electrocardiograph, although highly satisfactory, involves a complicated technique with photographic development. The extremely ingenious cardiotachograph developed by Dr. Ernst P. Boas of the Montefiore Hospital, New York, has been installed in one of the rooms of the Nutrition Laboratory and has been found to be very helpful. By means of this cardiotachograph, which V. Coropatchinsky has skillfully coupled with a Blix-Sandström kymograph with a spirally moving drum, we have been able to secure continuous pulse records over the entire morning. This has not only been of value in our studies of repose, particularly in the research on mental effort, but has also actually been successfully used in our muscular work studies, where the pulse rate approximated 150 beats per minute. This instrument we can strongly recommend as being one of the greatest aids in the study of heart rate.

EDITORIAL WORK

Articles that have been prepared for publication during the past year and that are soon to appear in print are as follows:

The energy metabolism of sheep. (E. G. Ritzman and F. G. Benedict. Univ. New Hampshire, Agric. Exper. Sta., Technical Bulletin 43, June 1930.)

A helmet for use in clinical studies of gaseous metabolism. (F. G. Benedict. New England Journal of Medicine.)

A multiple-chamber respiration apparatus for rats and other small animals. (F. G. Benedict. Journal of Nutriton, Sept. 1930.)

The metabolism of the albino rat during prolonged fasting at two different environmental temperatures. (K. Horst, L. B. Mendel, and F. G. Benedict. Journal of Nutrition, Sept. 1930.)

Metabolism studies on the wild rat. (F. G. Benedict and J. M. Petřík. American Journal of Physiology.)

Differential response of male and female ring doves to metabolism measurement at higher and lower temperatures. (O. Riddle, G. Christman, and F. G. Benedict. American Journal of Physiology.)

An apparatus for the exact and rapid analysis of gases from respiration chambers. (T. M. Carpenter, R. C. Lee, and A. E. Finnerty. Wissensch. Archiv für Landwirtschaft, 1930, volume 4.)

Factors affecting the energy metabolism of sheep. (F. G. Benedict and E. G. Ritzman. Wissensch. Archiv für Landwirtschaft, 1931, volume 4.)

The effect of muscular work upon the respiratory exchange after the ingestion of glucose and fructose. I: Apparatus and method of procedure. II: The relation of the mechanics of breathing to the respiratory quotient. III: Heat production, oxygen debt, excess respiratory quotient, and carbohydrate metabolized. (T. M. Carpenter.)

The basal metabolism of South Indian women. (F. G. Benedict and E. D. Mason.)

In addition, an article describing the Nutrition Laboratory's electric compensation calorimeter for small animals and its emission calorimeter for humans, illustrated with many detailed drawings, is now fairly well along in its preparation for publication in Abderhalden's Handbuch der biologischen Arbeitsmethoden. The Director's report of his 1929 tour of European laboratories and scientific institutions has been prepared in typewritten manuscript form, supplemented by numerous photographs, newspaper clippings, and lecture announcements. The editing of the majority of these articles has been in the hands of Miss E. A. Wilson.

The details of the extensive research carried out between 1915 and 1921 at the New York Zoological Park, on the metabolism of cold-blooded animals (snakes, tortoises, lizards, and alligators) are now being tabulated and charted in final form and considerable progress has already been made in the discussion of the results of this investigation.

PUBLICATIONS

(1) The Carpenter form of the Haldane gas analysis apparatus. Changes made in the apparatus and details regarding its use. Thorne M. Carpenter, Edward L. Fox, and Arthur F. Sereque. Jour. Biol. Chem., vol. 83, pages 211-230 (1929).

A description is given of changes in the compensating system of the gas analysis apparatus for the exact analysis of outdoor and respiratory chamber air, together with the method of adjustment for adequate compensation, of a modified pipette for potassium pyrogallate, of an alteration in the combustion unit for methane, of a short method of calibrating the measuring burette, and of an arrangement for operating by motor. Remarks are included on the use of the apparatus with special reference to dead space in sampling, water in burette, and preparation and storage of potassium pyrogallate, suitable size of tube for compressed air used for stirring in water jacket, variable atmospheric pressure, and tests for tightness and adequate compensation.

(2) Ethyl alcohol in fowls after exposure to alcohol vapor. Thorne M. Carpenter. Jour. Pharmacol. and Exper. Therap., vol. 37, pages 217-259 (1929).

The distribution of ethyl alcohol in the tissues of adult poultry was determined in hens after exposure to alcohol vapor for periods of from 2 to 29 hours. The highest concentration was usually found in the blood, although in some hens the brain and immature eggs had a higher concentration than the blood. The lowest concentration was in the fat. The liver contained little or no alcohol when the concentration in the blood was low, but contained about the same amount of alcohol per gram as the heart, lungs, kidneys, and spleen when the concentration in the blood was high. The lowest content of alcohol, irrespective of length of exposure, was found in the group of animals that were active during the entire period of exposure. The animals showed abnormal behavior when the concentration in the blood was above 2.5 mgm. per gram. The lethal concentration was between 3.7 and 5.6 grams per kilogram of body weight.

(3) The respiratory exchange after ingestion of levulose and dextrose, as affected by muscular work. Thorne M. Carpenter and Edward L. Fox. Amer. Jour. Physiol., vol. 90, page 307 (1929).

An abstract of a communication given at the XIIIth International Physiological Congress in August 1929.

(4) The gaseous exchange of the human subject. I: As affected by the ingestion of water at 37.0° C. Thorne M. Carpenter and Edward L. Fox. Journal of Nutrition, vol. 2, pages 359-374 (1930).

The respiratory exchange of a human subject was measured by means of the Benedict universal respiration apparatus and the gasometer method, for a period of one hour before and for 3½ to 4½ hours after the ingestion of 50 to 500 c.c. of water at 37° C. In control experiments without water under otherwise similar conditions, and in experiments with ingestion of less than 200 c.c. of water, the carbohydrate metabolism and the heat production changed but little. The ingestion of 250 c.c. of water was followed by a slight increase (4 per cent) in the metabolism of carbohydrate for a period of one hour. With 500 c.c. the carbohydrate metabolism was nearly doubled for 2 hours. The heat production was increased (2 per cent) for 1½ hours with 200 c.c., for 2 hours (1 per cent) with 250 c.c., and for 2 hours (7 per cent) with 500 c.c. of water at 37° C.

(5) The gaseous exchange of the human subject. II: As affected by small quantities of dextrose. Thorne M. Carpenter and Edward L. Fox. Journal of Nutrition, vol. 2, pages 375–388 (1930).

The respiratory exchange of a human subject was measured after the ingestion of from 5 to 104 grams of dextrose, in the same manner as in the experiments with the ingestion of water. All amounts of 10 grams or over were accompanied by a rise in the respiratory quotient, with the maximum in the third half hour. The increase in carbohydrate metabolism above basal for 3 hours represented from 17 to 31 per cent of the dextrose ingested in quantities of from 10 to 36 grams. The increase in heat production was practically 1 calorie for each additional 5 grams from 5 to 25 grams. Above 25 grams, the increase in heat production rose more rapidly in proportion to the additional amounts given. The increase in heat production amounted to from 4 to 6 per cent of the fuel value of the dextrose in 5 to 36 grams.

(6) The gaseous exchange of the human subject. III: As affected by small quantities of levulose. Thorne M. Carpenter and Edward L. Fox. Journal of Nutrition, vol. 2, pages 389–408 (1930).

The effect upon the respiratory exchange of the ingestion of levulose in amounts from 5 to 104 grams was determined in the same manner as reported in the two preceding articles. The highest respiratory quotients were found, for the most part, in the second half hour, the duration and height being greatest with the larger quantities. The increase in apparent catabolism of carbohydrate represented from 30 to 34 per cent of the ingested sugar, except that 5 grams gave an increase of 14 per cent and 15 grams of 53 per cent. The increase in heat production varied from 0.5 calorie after 5 grams to 46 calories after 104 grams, and represented from 2 per cent of the fuel value with 21 grams to 12 per cent with 104 grams. The probability is favored in a discussion of the significance of the respiratory quotient that the reaction after levulose is one of conversion of carbohydrate into an oxygen-poor substance (fat), even when the respiratory quotient does not rise above unity.

(7) The energy and the protein content of foods regularly eaten in a college community. Francis G. Benedict and A. Gertrude Farr. Univ. New Hampshire, Agric. Exper. Station, Bulletin 242, May 1929. 60 pages.

With the oxy-calorimeter a survey was made of the energy content of a large number of individual foods and of mixed meals served at the local restaurants and at the college cafeteria at the University of New Hampshire, in Durham, N. H. Nitrogen analyses were also made. The foods studied included breads, doughnuts, sandwiches, pies, ice cream, and candies, as well as typical breakfasts, dinners, and suppers. The cost of the different foods in relation to their energy value is considered. The data on mixed meals indicate that the energy value of the total food consumed per day, per week, or for any period of time may be estimated with a relatively high degree of accuracy by obtaining the air-dry weight (in grams) of a food mixture and multiplying it by the factor 5. This procedure does away with the necessity for using either the bomb or the oxy-calorimeter and gives the physician and the dietitian a simple means of calculating the energy intake with a degree of accuracy sufficient for most purposes.

(8) The measurement of the basal heat production of pigeons. I: Instrumental technique. Francis G. Benedict and Oscar Riddle. Journal of Nutrition, vol. 1, pages 475–495 (1929).

The various types of respiration apparatus devised and used in studying the basal metabolism of doves and pigeons are described in such detail as to permit of their duplication elsewhere whenever wanted. These types include: a closed-circuit respiration apparatus for a single dove and another for a pigeon; an open-circuit apparatus for a single pigeon; an open-circuit multiple-cage respiration chamber for 10 common pigeons, and a modification of this for use with 10 doves.

(9) The measurement of the basal heat production of pigeons. II: Physiological technique. Francis G. Benedict and Oscar Riddle. Journal of Nutrition, vol. 1, pages 497–536 (1929).

Several physiological factors that are conceivably capable of modifying the basal heat production of doves and pigeons have been studied. The elimination or control of these factors is essential to success in measuring such differences as may exist in the basal metabolism of the sexes, of different races, and of different hybrids among these birds. More than a thousand birds of known pedigree, maintained under excellent conditions, were continually available for this investigation. Among the factors studied were fasting, time of day, light versus dark, feeding by hand to insure a definite amount of food in the crop prior to the experiment, environmental temperature, activity, inactivity or close, prolonged confinement, and age. It is concluded that the probable "basal" values from doves and pigeons are to be sought among measurements made exclusively at night, in completely darkened chambers. This research has demonstrated that factors modifying the heat production of doves and pigeons exist in considerable number and complexity. Knowledge regarding the influence of these factors, together with the development of the apparatus and technique described in the preceding paper, now makes it possible to obtain reliable measurements of the basal metabolism of these birds.

(10) Dernières recherches du Nutrition Laboratory sur le métabolisme chez l'homme et les animaux. Techniques employées, données et conclusions. Francis G. Benedict. Bulletin de la Société Scientifique d'Hygiène Alimentaire, vol. 17, pages 321–352 (1929).

A publication in full of a lecture given before the Société Scientifique d'Hygiène Alimentaire in Paris, January 19, 1929. The special problems discussed are the metabolism of pigeons, geese, rats, and sheep as influenced by various factors, such as environmental temperature, fasting, age, confinement, crossing, and shearing; the metabolism of humans studied with various types of respiration apparatus during the muscular work of typewriting, riding a bicycle ergometer, and walking on a treadmill; the metabolism as influenced by race, particularly the metabolism of women in Madras, India; and a comparison of the heat production per square meter of body surface of humans and animals.

(11) **The energy requirements of intense mental effort. Francis G. Benedict and Cornelia Golay Benedict. Proc. Nat. Acad. Sci., vol. 16, pages 438–443 (1930).**

With the helmet and spirometer type of respiration apparatus the oxygen consumption or the energy needs of five men and one woman were measured during periods of mental repose and mental activity. The mental effort consisted in the solution, without aid of paper and pencil, of a number of problems in multiplication and addition. To rule out the influence of excitation or "attention," the metabolism was likewise measured during periods of response to a flashing light or an electric buzzer, the subject lightly tapping a telegraph key whenever the stimulus occurred. Simultaneous graphic records were obtained of the heart rate, the respiration rate, and the ventilation of the lungs. The results of this investigation show that with intense, sustained mental effort, such as in multiplication, there is a noticeable increase in the heart rate, a rather considerable change in the character of the respiratory movements, an increase in the volume of air passing through the lungs, a small increase in the carbon-dioxide production, a smaller increase in the oxygen consumption, and consequently a slight increase in the apparent respiratory quotient. The increase in oxygen consumption, which may be taken as the best index of energy transformations, is such as to suggest that the increase in heat production as a result of intense mental effort of this type can hardly be of the order of more than 3 or 4 per cent. In view of the sense of extreme, almost overpowering fatigue in both mind and body following sustained mental effort, it is surprising that mental effort has such an insignificant effect upon the general metabolism or level of vital activity.

DIVISION OF PLANT BIOLOGY

H. A. SPOEHR, CHAIRMAN

The new central laboratory of the Division, located at Stanford University, was dedicated informally on August 27, 1929. Most of the equipment was moved from Carmel and Berkeley during August, though the final installation and arranging required considerable time. The year's laboratory work suffered some from the interruption occasioned by the moving of apparatus and equipment and by the reassembling and readjusting of it in the new building. Much of this work required new and special mountings, benches, etc., and these were constructed entirely in the shop of the new laboratory. Similarly, the equipment of the preparation house, designed for work with plant materials on a small factory scale, was also constructed and mounted largely in the same manner. The new facilities in the laboratory building, the glass house and the gardens are proving highly satisfactory.

In the fall of 1929 the manufactured gas which was being supplied to the laboratory was replaced by natural gas. This necessitated changes in all laboratory gas appliances. While most of these changes could be made without great inconvenience, considerable difficulty was experienced with blast lamps, especially for purposes of glass blowing. Dr. Harold Strain has devised a blast lamp for use with natural gas which has been highly satisfactory and is finding extensive use.

During the past year the entire five acres of land now under lease have been fenced and the transplant plots within this area have also been carefully enclosed. A lath shelter, 24 by 34 feet, adjoining the glass house has been constructed, thus completing the first unit of equipment for the culture of plants used in the transplant experiments. The extension of the irrigation water lines for use in this area has also been completed. A roadway of macadam base with asphaltic surface has been laid and the necessary culverts installed.

Facilities for transplant experimentation have been considerably increased during the year through development of a base station in connection with Division headquarters at Stanford University and of a subalpine station at timber-line in the Sierra Nevada. At the latter have now been assembled all transplants formerly located at various places in the High Sierra. This arrangement permits of better control and at the same time facilitates detailed studies and direct comparisons between the forms represented. Advantage has been taken of natural conditions, including different slope exposures and moisture relations, and in addition a small area has been artificially shaded by covering with lath construction. Access to the station has been rendered possible through road extensions generously provided by the U. S. Forest Service, which agency also has provided the use of land in continuance of cooperative relations formerly entered into.

Space in the new laboratory building has been provided to care for the work on the records of the genetic experiments of Professor E. B. Babcock, which are in charge of Mr. C. W. Haney at Stanford University. Dr. William G. Young, a Fellow of the National Research Council, has also used some of the facilities of the laboratory during the year.

Dr. Heinrich Walter, of the University of Heidelberg and a Fellow of the Rockefeller Foundation, and Dr. Erna Walter spent six months at the Desert Laboratory investigating the osmotic value of the sap of a number of characteristic desert plants, with particular reference to seasonal and habitat differences. Dr. Bernard Meyer, Assistant Professor of Botany in Ohio State University, spent three months in the summer of 1929 at the Desert Laboratory in an investigation of the influence exerted on the water loss of cotton plants by differences in the salt content of the soil solution.

Dr. Mason Fraps, a Fellow of the National Research Council, has been in residence at the Desert Laboratory during the entire year, engaged in the continuation of his investigations on the oxygen consumption of *Planaria*. Dr. Fraps has also given some attention to the development of a method for the determination of water loss by plants in place, which is far more refined than any of the methods now in use, and also to methods for securing a continuous record of transpiration and accompanying physical conditions. Mr. E. H. Runyon, a graduate student in the University of Chicago, spent three months at the Desert Laboratory working on the germination behavior of *Covillea* and the early phases in its physiological life-history. Dr. Lee R. Dice, of the Museum of Zoology of the University of Michigan, assisted by Mr. Wm. P. Harris, spent two months in a field study of the distribution of rodents in the Tucson region, with particular reference to the habitat preferences of closely related species and subspecies.

Dr. Eduard Schratz, of the Kaiser Wilhelm Institut für Biologie, spent three months at the Desert Laboratory as a grantee of the Institution, after the termination of his tenure of a fellowship of the Rockefeller Foundation, completing certain phases of his work on the transpiration of desert perennials. Mr. Kenneth Hobbs, a graduate student in the Department of Zoology at Stanford University, spent several weeks at the Desert Laboratory in the spring of 1930 engaged in a field study of reptiles and in the collection of material for a study of the embryology of certain poorly known forms.

Dr. A. E. Douglass is spending the summer in Sweden in order to examine the field evidence of Pleistocene varves, and to become familiar with the methods by which they are being studied.

The collection of ring-sequences from the trunks of fossil trees in Yellowstone Park, which was begun last year, is being continued during the present field season. It is hoped that from the specimens made available for study, it will be possible to determine whether the varying conditions for tree growth during the Tertiary, as indicated by the nature of the rings in the fossil wood, were of the same order as those in modern trees.

GROWTH

CONTINUOUS AND NON-RHYTHMIC ACTION OF CAMBIUM, BY D. T. MACDOUGAL

The results of measurements of the rate of growth in trunks of the Monterey pine for 12 years by the use of the dendrograph support the conclusion of previous investigators that the periodic activities of many trees are seasonal effects.

The activities of the protoplasm of embryonic tracts, such as cambium, are not rhythmic to the degree that their rate of activity varies from that of the maximum to that of rest or near-inaction.

Intermittent growth may in some cases be ascribed to the deterioration of highly differentiated organs such as leaves or roots, which may bring the activities of a plant to a pause until a new suite of the worn-out organs is developed. This is illustrated by all deciduous plants.

Organisms, such as evergreen trees, especially of coniferous types, in which several suites of leaves are maintained are capable of showing continuous growth at a rate directly respondent to environic agencies. The growth of a pine tree uninterruptedly for three years, and its action during three years with pauses of only a few days, have been described.[1] The reputed continuous growth of trunks of trees in rainy tropical regions is yet to be tested.

The Pneumatic System of Trees, by D. T. MacDougal

The continuation of studies on the constitution of the mixture of gases in the wood of trees and other plants begun several years ago has confirmed earlier conclusions as to the relation of the proportion of carbon dioxide present to growth and respiratory activity.

It is now becoming apparent that the proportion of this gas may also have some reflection on tensions and pressures in the hydrostatic system of trees.

Long-lived Cells in Trees, by B. J. G. Brown and D. T. MacDougal

The fact that cells in massive stems of woody trees and succulents may continue in an active condition for periods of one to four hundred years as discovered by MacDougal in 1926 is now being followed up by an intensive study of the soft stems of "palo verde" (*Parkinsonia microphylla*) of the Arizona desert. Only parenchymatous cells of the medulla or pith or in its rays in all trees examined, except *Parkinsonia*, are long-lived.

In this tree various types of differentiated cells are found alive and in positions indicating an age of one, two, three or more centuries. As a logical result of such continued life, about three-fifths of the total volume of the trunk of this tree is made up of living cells. If the cambium cylinder of this tree be considered, it may be said that its action is patchy and intermittent. Additions to the diameter of the trunk at any place may not take place over periods of one, two or three years.

Dendrographic Measurements, by D. T. MacDougal

The series of dendrographic records of changes in diameter of trees begun with the invention of the dendrograph in 1918 has been continued. Instruments are attached to one tree of *Populus*, one of *Parkinsonia* and one of *Carnegiea* at Tucson; one on *Juglans* and twelve on *Pinus* at Carmel. A suite of eleven on the California redwood (*Sequoia sempervirens*) at a locality a few miles south of Carmel is now making the seventh year's records of this interesting tree. Activity in some trees of this species in every month of the calendar for 1929–1930 to date has been noted for the first time. The file of dendrographic records as it is being kept affords information bearing on many phases of activity of massive plants.

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[1] D. T. MacDougal, *Lengthened growth periods and continuous growth*, Proc. Amer. Phil. Society, vol. 69, 329, 1930.

LENGTHENED GROWTH PERIODS IN TRANSPLANTS, BY D. T. MACDOUGAL

A number of woody plants and trees were transplanted from an elevation of 7000 to 8000 feet on the Santa Catalina Mountains, an "island range" in the Arizona desert, in 1906. The transferal was from a locality in which a season of 40 to 60 days was possible to an environment in which growth for a season three times as long was possible. Dendrographic records of the Arizona walnut tree have been made in both places and especial attention is being given to two species of oaks.

The results of the observations show that various correlations are disarranged in the lengthened periods of activity. It is readily apparent that if a plant be placed under conditions which induce or permit any one of the several embryonic tracts which may be involved to display relatively higher rates, or which come into activity earlier or later than in the normal or accustomed sequence, organs or tissues may be formed which present unusual aspects.

Furthermore, hormones such as are supposed to emanate from awakening buds may be released prematurely and induce unwonted action in cambial layers and vegetative points. The possible disturbances which may result would make a long list. One of the most direct and obvious is the awakening of two processes simultaneously which ordinarily come one after the other. This is illustrated by the concurrent formation of wood and development of nuts in *Juglans* in a coastal location, while the leaf products are chiefly converted to wood in the earlier part of the season in the habitat of the tree and are later available for the rapid development of the nuts which do not appear until about the end of the period of wood-formation. The case is not a simple competition for leaf-products, however.

According to the results of Kraus and Kraybill, relatively high nitrogen content of nutritive solution retards reproductive action, while relatively high carbohydrate formation increases flowering and fruit formation. It is to be noted that the early formation of leaves and their continued action through a longer season would tend to an accumulation of sugars and to a heightened ratio of carbohydrates to nitrogen early in the season.

The shells of the nuts are heavier by the deposition of woody material, with diminished rugosity. X-ray images show other distinctive features. The results of similar analyses of stem and leaf-structures are yet to be described. The differences between the general appearance of this tree grown on a mountain range at 8000 feet elevation and when transplanted to sea-level in an equable climate are notable.

PHOTOSYNTHESIS AND CARBOHYDRATE CHEMISTRY

CHEMICAL STRUCTURE OF YELLOW LEAF PIGMENTS, BY J. H. C. SMITH, H. A. SPOEHR, AND HAROLD W. MILNER

The primary aim in the work of this section during the past twenty years has been directed toward a more accurate and detailed account of the dynamics of the photosynthetic process in the living plant. Many phases of this problem have been treated and considerable insight into this mechanism has been gained. It became evident that a clearer concept of the rôle played by the yellow pigments was necessary; but before reliable information as to their biological significance could be obtained, a thorough knowledge of their chemical nature was essential. Therefore an investigation of the chemical constitution of carotene and xanthophyll was undertaken. The progress made on this problem has been most gratifying and this year it can be reported for the first time that the general nature of the structure of these molecules, carotene and xanthophyll, is defined.

Additional interest has come to this problem from the discovery that carotene possesses many similarities to vitamine A in its biological reactions. Therefore, the chemical knowledge which has been gained of the carotene molecule is of particular significance in the interpretation of biologic activity in terms of chemical constitution.

OXIDATION OF CAROTENE AND XANTHOPHYLL

The Oxygen Equivalent of Carotene and Xanthophyll—Because the oxygen equivalent had been found useful in substantiating certain structures proposed for some of the carotenoid pigments, it seemed desirable also to determine this value for carotene and xanthophyll. The oxygen equivalent is defined as "the number of oxygen atoms used by one mol of a substance when oxidized with potassium permanganate." Since the usual methods for determining this quantity were not applicable to the pigments in question a new technique was developed whereby the oxidations were carried out in pyridine solution.

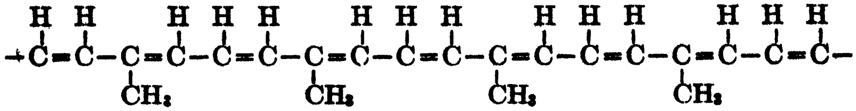
It was found that the oxygen equivalent of carotene is 41.97 and of xanthophyll 53.27.

Carotene has the formula $C_{40}H_{56}$, xanthophyll $C_{40}H_{56}O_2$; their chemical reactions indicate a similar constitution, differing primarily because of the substitution of two oxygen atoms in xanthophyll. The fact that xanthophyll has been found to have a higher oxygen equivalent than carotene suggests that the former is split and further oxidized at the position of substitution of the oxygen atoms in the xanthophyll molecule. This would lead to the conclusion that the oxygen atoms are present in a hydroxyl or ketone structure. Recent work has shown that they are present in the molecule as hydroxyl oxygens.

Volatile Acids from Carotene and Xanthophyll—By oxidation of carotene with potassium permanganate in aqueous solution it was shown previously that acetic acid was formed. It was impossible, however, to obtain quantitatively the molecular ratio of acetic acid formed to pigment oxidized. Recently a method satisfactory for this determination has been developed whereby the pigment is oxidized in pyridine solution by potassium permanganate and the volatile acids estimated and identified. The determination of the nature of the acids thus formed was made possible by the development of a micro-modification of Dyer's method for the identification of volatile organic acids.

By this procedure it was established that 4 mols of acetic acid are formed per mol of carotene or xanthophyll oxidized.

This combined with other observations to be described later can be explained best on the assumption that the following grouping exists in these molecules:



$$-\overset{H}{C}=\overset{H}{C}-\underset{CH_3}{C}=\overset{H}{C}-\overset{H}{C}=\overset{H}{C}-\underset{CH_3}{C}=\overset{H}{C}-\overset{H}{C}=\overset{H}{C}-\underset{CH_3}{C}=\overset{H}{C}-\overset{H}{C}=\overset{H}{C}-\underset{CH_3}{C}=\overset{H}{C}-\overset{H}{C}=\overset{H}{C}-$$

Oxalic Acid from the Oxidation of Carotene—In continuation of the work on the oxidation of carotene with potassium permanganate in pyridine solution it was hoped to determine directly the number of conjugated double bonds in the molecule from the number of acetic and oxalic acid molecules obtained on oxidation.

Experiments with compounds of known structure showed, however, that the theoretical quantity of oxalic acid is not formed by this oxidation. The oxidation of carotene by this method yields 2.4 mols of oxalic acid per mol of pigment oxidized and, although no definite conclusions regarding structure can be drawn from this value, efforts are being continued to perfect this means as an aid in the determination of chemical structure.

HYDROGENATION OF CAROTENE

Catalytic hydrogenation has been found to be the best means available to determine the number of double bonds in an unsaturated molecule and to distinguish between double bonds and the more stable ring structures. For this reason the work on the hydrogenation of carotene has been continued so that it might throw additional light on the unsaturated nature of the carotene molecule.

The hydrogenations have been carried out with aluminum amalgam and with both small and large quantities of platinum oxide catalyst relative to the amount of pigment used. By varying the conditions in this way it has been possible to attain step-wise hydrogenations, and from the properties of the products thus formed to deduce certain facts concerning the structure of the molecule.

Reduction with Aluminum Amalgam—In the report of last year it was stated that carotene could be reduced by aluminum amalgam in ether solution, but that the number of hydrogen atoms added could not be definitely stated. A method has now been found by which the reduction is carried out much more quickly than formerly and a product obtained which shows definitely that two hydrogen atoms have been added to the carotene to give dihydro carotene, $C_{40}H_{58}$. The rapid hydrogenation by this means produces a decided decrease in the color; the resulting dihydro carotene is an orange viscous oil which could not be crystallized. Combustion analyses show that two atoms of hydrogen have been absorbed by the carotene in this method of hydrogenation.

When dissolved in alcohol, dihydro carotene showed a specific rotation of +38.9° and an absorption spectrum maximum at $\lambda=320\mu$. When compared to the corresponding properties of carotene, optical rotation −71° (solvent carbon disulfide) and absorption maximum at $\lambda=478\mu$, it is seen that a great alteration in the structure of the molecule has been effected.

By comparing the shift in the absorption spectra of various compounds with the number of double bonds present in the molecule, a fairly definite rule can be formulated relating the number of conjugated double bonds with the absorption maxima. Since the color in these carotene derivatives is due to conjugated double bonds, we have a means of judging the change in the number of conjugated double bonds from the absorption spectra. On this basis, dihydro carotene contains three less double bonds in the conjugation system than carotene. Only one has been removed by addition of hydrogen, therefore the other two must have been cut off by interposition of the added hydrogen.

R. Kuhn has shown that only double bonds in proximity to rings are attacked by aluminum amalgam. Conversely we believe that since carotene is acted on by this agent, it is evident that the conjugation system in carotene probably lies in proximity to a ring system or systems.

Hydrogenation with Platinum Oxide Catalyst—In the last report it was shown that when a small ratio of platinum oxide catalyst to carotene was used in the catalytic hydrogenation of carotene a compound containing 18 additional hydrogen atoms was formed. This indicated that 9 of the double bonds in carotene were different from the others. Furthermore the molecular refraction showed that the unsaturation not removed by hydrogenation could be explained by two rings of bi-cyclic nature similar to the thujane ring. This compound also possessed a considerable dextro-rotatory power.

By using the same method and increasing the ratio of catalyst to carotene, a compound, called eikosa-hydro carotene, has been prepared which contains 20 additional hydrogens, $C_{40}H_{56} + 20\ H = C_{40}H_{76}$.

The product thus formed gives the following analysis: Found, C, 86.21; H, 13.87; Theory, C, 86.23; H, 13.77.

The physical properties were observed and found to be: Specific rotation without solvent = +0.34°, density = 0.8748, refractive index = 1.4821, molecular refraction (mol. wt. of 556.6) =181.42, molecular refraction calculated = 180.32, exaltation = +1.10.

Since the exaltation for a double bond is 1.733, it hardly seems probable that the remaining unsaturation is due to double bonds.

Zechmeister has shown that a compound containing 22 additional hydrogen atoms is possible. To saturate the molecule completely a total of 26 hydrogen atoms is required. Since the last two mols of hydrogen have never been added, it is logical to suppose that the remaining unsaturation is due to two stable rings.

Combining these findings we proposed the hypothesis that the last two unsaturated linkages which are able to be hydrogenated catalytically are due to three membered rings which form bicyclic rings similar in nature to the carane or thujane rings.

The change of optical activity on hydrogenation may throw some light on the structure also. The carotene molecule has been found to be optically active. The hydrogenation derivatives containing 2, 18 and 20 atoms of hydrogen additional are also optically active. Zechmeister, however, states that the compound containing 22 additional hydrogens is probably optically inactive or has an immeasurably low activity. If it has no activity then the optical activity of the molecule is destroyed by the addition of the last mol of hydrogen, and the last unsaturated linkage causes asymmetry in the molecule.

OZONIZATION OF CAROTENE

In the last report some results were given which were obtained from the ozonization of carotene. Since then, additional experiments have been carried out on this phase of the problem.

From the hydrolyzed ozonized product of carotene and xanthophyll the volatile constituents were distilled. Tests for the aldehydes were positive, but for acetone were negative. The latter finding is very important for structural considerations. This shows that the group $(CH_3)_2C=$ does not exist in the carotene and xanthophyll molecules. It has been found in the lycopin molecule, however, and shows a point of difference in the two molecules.

To arrive at quantitative ideas as to the number of double bonds present in the molecules, a new apparatus has been devised whereby the amount of ozone absorbed by the substance may be determined quantitatively. The method consists in determining the amount of ozone in the gases passing into the ozonization flask and making a similar determination of the ozone flowing from the reaction flask. By determining the total amount of gas which flowed through the system, the amount of ozone absorbed by the reacting system is estimated. While the error in the method is about 10 per cent at the present time, it gives promise of being developed into a very useful quantitative method for the determination of unsaturated linkages in organic molecules. The method is much simpler than the isolation and combustion of the ozonides formed.

By this method carotene showed 10.5 double bonds and xanthophyll 11.3. Further work is in progress on this method.

REACTIONS OF TRIOSE SUGARS, BY H. A. SPOEHR AND HAROLD H. STRAIN

The significance of the triose sugars in both the catabolism and synthesis of the commonly occurring hexoses has been briefly set forth in previous reports. In the chemical reactions which result in these transformations there is such a large number of compounds involved, which possess almost identical chemical properties, are relatively highly reactive and are easily converted into each other, that identification by either chemical or physical means has proved to be exceedingly difficult. Yet an understanding of the chemistry of carbohydrate catabolism and synthesis depends upon a thorough knowledge of the various compounds which are intermediate and end products in these reactions. The immediate objective in these investigations has been a better knowledge of the properties of the compounds concerned, with a view to developing methods for their quantitative estimation, so that ultimately their reactions under conditions which may be expected to exist in the living cell may be more carefully studied.

The redetermination of the reducing power of glyceraldehyde toward Benedict's solution has resulted in a value 1.145 times that of glucose. Hence the oxidation of one mol of glyceraldehyde by this method requires 1.68 atoms of oxygen. It has been found that this triose is readily reduced by means of a platinum oxide catalyst and hydrogen in water solution or in solution with disodium phosphate; while in neutral phosphate or acid solution the reduction is very slow.

The other triose, dihydroxyacetone, is quite unstable even in the crystalline state and undergoes autocondensation readily. There are apparently two distinct condensation products formed and there is some indication that this triose is also spontaneously converted to methylglyoxal to some extent. It has been necessary, therefore, to work out methods of purification. The reducing power toward Benedict's solution has been found to be 1.11 times that of glucose and hence required 1.63 atoms of oxygen for oxidation. Dihydroxyacetone is also readily reduced to glycerine with hydrogen and a platinum oxide catalyst in water solution and in glacial acetic acid.

For the preparation of methylglyoxal, the method of Denis has been used and some improvements developed so that a product was obtained, which, on the basis of available analytical methods, consisted of about 80 per cent methylglyoxal. In previous work, both chemical and biological, not sufficient consideration has been given to the fact that it is exceedingly difficult to obtain pure methylglyoxal nor has the nature of the impurities been determined definitely. Analysis by combustion does not give definite information regarding the purity of the preparation, because the possible contaminations may have the same empirical formula, *e.g.*, lactides. This fact has been frequently disregarded. Efforts to obtain a pure crystalline product have not yet succeeded. On fractionally distilling the crude methylglyoxal in vacuum, the bright yellow-green, mobile, monomolecular form can be collected in the receiver cooled with solid carbon dioxide. On standing, at temperatures above 0° C., this goes over spontaneously into a thick colorless glass.

There are no satisfactory methods for the determination of methylglyoxal, especially in cases where carbohydrates or related substances are also present. For this reason considerable time has been devoted to the development of such methods. From the wide variety of addition compounds which were studied, the following proved to be the most satisfactory as a means of determining methylglyoxal in this manner: the phenylosazone, m.p. 148°, the *p*-bromphenylosazone, sinters 184°, the *p*-nitrophenylosazone, m.p. 280°, the *m*-nitrobenzoylosazone, m.p. 280°, the disemicarbazone, m.p. 254° and the 4, 4-diphenylsemicarbazone, m.p. 162°.

A comparative study was made of the determination of methylglyoxal by different methods; these included the precipitation of methylglyoxal in the form of some of the compounds just mentioned, the conversion into lactic acid with an excess of alkali, oxidation with hydrogen peroxide in the presence of sodium hydroxide according to Friedemann[1] and the method of Fischler and Boettner.[2] These methods gave only fairly consistent results; the maximum difference amounted to about 4 per cent. The lactic acid method and that of Fischler and Boettner gave lower results than the others. Experiments with this method also revealed the fact that a decided excess of both alkali and iodine must be used. The reducing power of methylglyoxal toward Benedict's solution has been found to be about 35 per cent that of glucose. Further critical examination and increase in the precision of these methods obviously depends upon the preparation of absolutely pure methylglyoxal, a task belonging to the field of synthetic organic chemistry.

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[1] T. E. Friedemann, Jour. Biol. Chem., vol. 73, 331, 1927.

[2] F. Fischler and R. Z. Boettner, Z. analy. Chem., vol. 74, 28, 1928.

It should be emphasized again that the object of these investigations is the determination of the chemical processes and steps involved in carbohydrate metabolism; the development of methods is essential to this end.

Under the influence of strong alkalies the hexose sugar molecule undergoes changes similar to those which occur in the living cell; methylglyoxal is formed from hexoses, and glyceraldehyde and methylglyoxal are converted into lactic acid. With lower hydroxyl ion concentration, however, the course of the reaction is considerably modified. Under such conditions, *e.g.*, in solution with disodium phosphate or sodium carbonate, glyceraldehyde is not converted into methylglyoxal but undergoes primarily a condensation, most probably to hexoses. Furthermore, no definite evidence of the conversion of glyceraldehyde into dihydroxyacetone, or vice versa, could be obtained under these conditions. Dihydroxyacetone undergoes a similar condensation, although a slight conversion to methylglyoxal also takes place.

Similarly, methylglyoxal, which with stronger alkalies is readily converted into lactic acid, does not undergo this change in solution with disodium phosphate or sodium carbonate. Under these conditions the reducing power toward Benedict's solution shows a decided increase, about 15 per cent, which is maintained for 16 days. At the same time the methylglyoxal in the solution decreases rapidly until finally only traces thereof remain. The exact constitution of the condensation product thus formed from methylglyoxal has as yet not been definitely determined. From the evidence thus far obtained it is quite certain that this product is not a triose. The number of theoretically possible compounds which could be formed from the condensation of methylglyoxal through aldol or benzoin condensation is very great and it is evident that considerably more experimental work will be required in order to determine the nature of the condensation which occurs under these conditions. No doubt the fact that methylglyoxal may undergo such a variety of reactions contributes to its importance as an intermediate product in carbohydrate metabolism.

EFFECT OF AMINES UPON THE CONVERSION OF THE TRIOSES INTO METHYLGLYOXAL, BY HAROLD H. STRAIN

The necessity of developing a method for the differentiation of the two trioses, *dl*-glyceraldehyde and dihydroxyacetone, led to the use of organic amines as possible reagents. While carrying out this investigation the surprising observation was made that many amines cause the formation of methylglyoxal from glyceraldehyde, a transformation similar to many of those taking place in biological processes. Further investigation revealed that glyceraldehyde, which is ordinarily quite stable in dilute acetic acid solutions, was transformed by some of these amines to slightly soluble methylglyoxal-amine compounds. In the presence of very small quantities of these amines, free methylglyoxal accumulates in solution, although the yields of methylglyoxal were never more than 50 per cent of the theoretical.

By carrying out the reaction in the presence of *m*-nitrobenzhydrazide, which was found to combine with methylglyoxal to form the very slightly soluble *m*-nitrobenzoylosazone of methylglyoxal, it is possible to convert glyceraldehyde completely into methlglyoxal (isolated as the *m*-nitrobenzoylosazone).

Of the 68 organic compounds which were tested as catalysts, only those containing the amino group were found to be active. Moreover, very few aliphatic amines were active, while most aromatic amines were excellent catalysts, specific examples of which are aniline, *p*-toluidine, chloroaniline, α- and β-naphthylamines and *p*-anisidine.

Dihydroxyacetone is slowly and incompletely converted into methylglyoxal in dilute acetic acid solution. Amines have but little effect on this reaction.

As a result of these observations a method has been devised for the determination of methylglyoxal and glyceraldehyde in the presence of hexoses. By the use of *m*-nitrobenzhydrazide it has also been possible to separate methylglyoxal from its condensation product and to determine methylglyoxal in the presence of phosphates—a separation impossible with the common hydrazine reagents.

A NEW METHOD FOR THE DETERMINATION OF MOLECULAR WEIGHTS, BY H. H. STRAIN AND J. H. C. SMITH

Two years ago work was begun on a new method for the determination of the molecular weights of compounds which had high molecular weights and low solubility. The need for such a method was continually brought to our attention because of our work with plant pigments and complex carbohydrates.

The principle of the method is that two solutions in the same solvent will come to the same molecular concentration if they are confined in contact with the same vapor phase.

Substance	Mol. Wt. Obs.	Mol. Wt. Theory
Diphenyl amine...	133	169
Resorcinol....... ..	103	110
Thymol..........	164	150
Naphthalene.......	140	128

In practice two solutions in the same solvent are made, one containing a known weight of a compound with known molecular weight and the other a known weight of a compound with unknown molecular weight. These two solutions are introduced into an H tube in which the middle portion is bent in the shape of an inverted U. One end of each of the limbs of the H tube is graduated so that the volume of the solution can be determined. The apparatus is evacuated and sealed and allowed to stand at any desired temperature until no further exchange of solvent occurs between the two solutions. Then the two solutions are at equal concentrations and the molecular weight of the unknown can be calculated.

While the method was usable with organic solvents it was exceedingly slow. In casting about for a better solvent it was found that liquid ammonia had most of the desired characteristics. Furthermore this procedure gave a method which was more practicable with liquid ammonia than any of the methods tried heretofore with this solvent. Several experiments were carried out in this solvent and some of the results are given to show the applicability of the method.

Since mannitol has been shown to behave normally in liquid ammonia, it was chosen as the reference substance in the molecular weight determinations.

It is probable that with certain modifications this method will afford an accurate means for the study of the problems of solution in liquid ammonia.

ISOLATION OF *d*-MANNOSE FROM SEEDS OF THE GUADALUPE PALM (*Erythea edulis*), BY HAROLD H. STRAIN

The seeds of the guadalupe palm were picked before they were quite mature. The hulls were then pared off with a knife and the kernels crushed in a vise, ground in a grinder and dried at 100° C. The dried pulp was extracted with 10 times its weight of boiling one per cent sodium hydroxide, dried, and hydrolysed with 75 per cent sulfuric acid as described by Clark.[1] The resulting sirup was found to contain 68.4 per cent mannose, determined as the phenylhydrazone.

EXPERIMENTAL TAXONOMY

INVESTIGATIONS UNDER THE DIRECTION OF H. M. HALL

The investigations of this section have as their definite objectives (1) contributions towards a rational and complete classification of the products of organic evolution, and (2) an increase in understanding of the processes operative in the development of these products. The first requirement for the attainment of these objectives is information as to species composition, by which is meant the various combinations of ecologic forms and genetic units that compose races, species and species groups. When such facts are at hand, especially for polymorphous groups of world-wide dispersal, the basis is laid for a study of such changes as may have occurred in connection with geographic distribution, including losses and additions to the ancestral stock during migrations, and mutational, selective and other processes involved in the evolution of animals and plants.

During past years our taxonomic studies have covered a wide range of subjects. Transplant experiments have been made with about 500 species distributed over some 40 families of flowering plants. This has provided a valuable background for more intensive studies of limited groups and has at the same time indicated subjects best suited to this purpose. These considerations have led, during the current year, to a restatement of the program whereby increased attention will now be given to selected genera and species, while the more general studies will be continued only as they give promise of specific value in solving evolutionary problems or as illustrating methods in taxonomic research.

In the following pages each of the selected groups is reported upon by the investigator most immediately concerned. In actual practice each member of the section takes part in all of the studies and shares in results to a much greater extent than this arbitrary division would seem to indicate.

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[1] Clark, U. S. Bureau of Standards, Scientif. Papers, No. 429, 1922.

The high value of the subalpine station at timber-line in the Sierra Nevada and the more extensive one at Mather, the latter at a middle altitude, lies in the opportunity they offer not only for testing effect of various climatic complexes upon plant structures but also for correlating results obtained in control experiments with forms as they actually occur in nature. Throughout the work, all plants are grown under as nearly natural conditions as possible, but not necessarily under those to which they are now best adapted, the aim being to test stability of characters and to induce only such modifications as might have arisen without the aid of man. Thus laboratory and field are brought together in an attempt to explain the origin of natural forms.

THE GENUS POTENTILLA, BY H. M. HALL

The superior qualities of these rosaceous plants for experimental studies were pointed out in the preceding annual report, and further trial in the transplant areas has confirmed the opinion there expressed. The only difficulty has been an infestation at the base station by a destructive crown-borer, but this has now been overcome through application of methods courteously worked out by Professor R. W. Doane, of Stanford University. As a result of the attack, the investigations at this station received a set-back of one year but none of the cultures was lost, each being perpetuated by means of propagules cared for in the glass-house until the field could be rendered free from the pest and made ready for replanting. Now that the nature of the trouble is understood, it should be possible to ward off new infestations at Stanford and, fortunately for the experiments, the crown-borer appears not to thrive at the mountain stations.

The studies in *Potentilla* are aimed especially at an understanding of composition of polymorphous species and of natural relationships between closely similar forms. As a basis for these studies it is necessary to know the extent to which both the individual and the species may be modified and to distinguish between temporary modification and permanent change. It now appears, however, that individual and racial development are intimately associated and that any factor operative in production of change may be of evolutionary significance.

Studies in individual modification in *Potentilla* are proceeding concurrently with taxonomic studies of species and races. Significant results in the former field include the following: In the group known as *P. gracilis* the leaves are normally palmate and the number of leaflets is fairly constant for each subspecies. However, by moving a plant, in which the leaflets are normally 7 for each leaf, into rich soil constantly irrigated, the number increases to 9, and each leaflet, now exceptionally large, has a tendency to become deeply lobed or cleft. In addition, the tissues between the points of attachment become so elongated as to render the entire leaf subpinnate, at least in appearance. Similar effects are produced by stimulation with fertilizers and are doubtless connected with increased metabolism. In *P. breweri* the leaflets are increased not only in size and number but in extent of dentation when plants are moved from their normal habitat at 9000 feet altitude to transplant areas at 4500 feet. Under these conditions the total number of indentations is more than doubled, or, in specific cases, from an average of 70 to an average of 160. In all of these experiments controls taken from the same root by means of vegetative divisions and held under original conditions failed to undergo these changes. An understanding of the exact nature of the modifications calls for detailed studies in anatomy and physiology, while a closer analysis of the causes would involve rigidly controlled ecologic experiment in the laboratory.

Potentilla rupestris (in the broadest sense) has been selected as the best subject for the investigation of the composition of species, ecotypes and races. The American forms are being assembled in transplant series for experimental and comparative studies and, although only a beginning has been made, certain definite results are already at hand. Thus, it has been established that flower-color is a constant character but that its use must be accompanied by such safeguards that it is scarcely available for general taxonomic purposes. Only fresh flowers are dependable, since the color in some forms changes from light cream to yellow in the press within a few hours. This ephemeral nature of the color has led to the erroneous description and consequent misplacing of at least one of the species (*monticola*). Petal-length is also constant within fixed limits for each form but can be artificially modified by as much as 10 per cent in the cultures. The spacing of petals, which in turn depends upon width of hypanthium, is a still better criterion for field and garden use. In some forms the hypanthium is so narrow that the petals nearly or quite meet along their margins; in others the petals are so widely spaced that a broad band of green sepal tissue is seen between contiguous pairs. This distinction indicates a clear and constant genetic separation and is not modifiable by any of the ecologic methods employed.

Although much too early to predict the final outcome, it appears that most or possibly all of the "small species" heretofore proposed in this group represent genetic types, but that the number of these which might be described is much greater than any systematist would be willing to accept as taxonomic units. It is hoped that a classification of all the forms on the basis of intensive field studies, transplant experiments and morphologic comparisons, accompanied by cytologic and genetic investigation, may throw light upon the manner in which new forms and species arise under natural conditions, and especially upon changes in composition that have occurred in connection with past migrations.

PENSTEMON INVESTIGATIONS, BY DAVID D. KECK

For the past year, the work on this genus has been a direct contribution toward a taxonomic monograph on *Penstemon*. It is planned to include in this, in addition to conventional data obtained by consideration of external morphology and geographic distribution, an assemblage of evidence from experimental ecology and physiology, and from cytology and genetics. Such a program calls for joint attack on the genus by workers in various fields, and such cooperation is being effected.

It has been determined that in a genus so large, it is highly desirable to make a preliminary survey of the situation from the taxonomic viewpoint, thus classifying the more pronounced groups found in nature and pointing out those places in particular need of further study.

The section *Saccanthera* has been surveyed in this manner and as treated contains 17 species. These have been segregated into two subsections largely on a basis of origins. One of these contains but the single species, *Penstemon bridgesi*, whose ancestry appears to lie in the section *Elmigera*. The other subsection includes the remaining species and seems to have arisen along three diverging lines of evolution from the *Penstemon gracilis* group in the section *Eupenstemon*. It is judged from examination of the present-day forms that these three lines lie closely together in *Eupenstemon*, but fail to converge at a single point, having arisen at different loci in a series of closely allied species.

One line of development within this subsection of *Saccanthera* consists of the single species, *Penstemon gracilentus*. The apparent connections are between this species and *P. procerus*.

A second line of development appears to have originated in the region of *Penstemon humilis* and *P. radicosus*. *Penstemon cusicki* is considered the primitive type of this line and to be the probable predecessor of the Utah species of the subsection, which has progressed in one direction, and of one Nevada and six California species that have developed in another. These latter are among the most interesting in Saccanthera, for numerous subspecies link them together and render the probable relationships less difficult to trace. Among these, morphologic change seems to be closely correlated with migration. This is demonstrated by noting that additional morphologic differences occur in each species that becomes more widely separated than the preceding from the place of probable origin. These differences seem to occur in just the sequence that would be expected as the group migrated along the routes which best evidence indicates as their natural lines of dispersal. Originating in southwestern Idaho, the group progressed through Nevada into California at about the region of Lake Tahoe, from which its lines of migration appear to have followed the mountains both north and south, the northern line reaching into central Oregon, and, by way of the Siskiyou Mountains, into the Coast Ranges, whence it extended south and nearly met the southern line which had followed the general direction of the Sierra Nevada to southern California. In this line the connections are so close in places that the delimitation of subspecies, and even species, becomes difficult. Transplant experiments, however, show that these have obtained considerable stability, containing many fixed biotypes. By correlating garden and herbarium information, it has been shown that nine distinct biotypes exist in the known collections of *P. azureus typicus* alone. Perhaps the most interesting case is a species that appears to have arisen through hybridization of *lætus* and *azureus*. It represents a good intermediate between these species, since the characters of each are distributed about equally within it. No characters peculiar to this new species have been discovered thus far, which fact, combined with its relatively limited distribution, is taken to suggest its comparative youth.

It has aged sufficiently, however, to occupy abundantly considerable territory from which neither of the supposed parents is known.

A third line of evolution within this subsection includes five species of the northwestern United States differing from the others in their toothed or lobed leaves. Their probable origin is in the group represented by *Penstemon ovatus* and *P. pruinosus*. The five are very distinct from one another and appear stable, only the two closely related species, *richardsoni* and *triphyllus*, showing much of a tendency to produce distinct biotypes which in time may become sufficiently definite or isolated to deserve nomenclatorial recognition.

This study of *Saccanthera* has brought to light many problems as to the units entering into the composition of the various species and as to geographic distribution, biotype origin, and relative stability of forms. These problems are now being subjected to field study and garden experimentation for solution.

STUDIES IN ZAUSCHNERIA, BY WM. M. HEUSI

An intensive investigation of this small but complex genus is being developed along three lines, *viz*, (1) taxonomy of existing forms as determined by field and herbarium studies, (2) the determination of the extent to which given forms may be modified by varying the ecologic conditions, and (3) genetic and cytologic studies, with special reference to the rôle of hybridization, mutation and chromosomal behavior in the creation of new forms.

Some progress has been made in the study of forms as they exist under natural conditions. The limited geographic distribution of *Zauschneria* makes possible the checking of herbarium studies with field observations, so that a fairly complete picture of the composition of the genus can be had.

Transplant experiments designed to test the extent to which a given individual may vary in different environments such as may be found in nature reveal with certainty that appreciable modifications occur. These are especially pronounced in vegetative characters, such as width of leaf, texture of leaf, density of pubescence, length of internode, and in number of fascicled leaves, while a range of less magnitude is found in color and size of flowers and in general habit of growth. A form from Calistoga, California, originally with narrow, canescent leaves became so different in appearance when grown in a semi-shaded garden at Mather that it would ordinarily be considered as of very different origin. The most evident changes were increased size and breadth of leaves and reduction in density of pubescence. Variations with season and stage of growth are also noteworthy. A plant from Topango Cañon, near the coast of southern California, exhibited all the essential characters of the extreme narrow-leaved form known as *Zauschneria cana*. When root divisions from this plant were grown in pots in a greenhouse they produced shoots which during one stage of growth were quite broad leaved and were more nearly referable to *Z. californica typica*, but leaves produced later in the season approximated those of the original form. Other facts equally significant should be noted. A plant of the moderately narrow-leaved group (*Z. californica typica*) from Lompoc, California, alters its size and texture of leaf and its habit of branching when grown in a shaded garden at Mather. Here it simulates the typical broad-leaved mountain forms (*Z. latifolia typica*) but it is nevertheless like none of these, for when the two are grown in the same garden each retains its individuality. The taxonomist, then, is confronted with two variables which need to be taken into account in classifying Zauschnerias—the genetic factors and the ecologic.

The genetic variations, as judged from field and transplant studies, appear complex. Distinct differences appear among plants growing under apparently identical or similar conditions. Series of cultures of such variants have been assembled from Hetch Hetchy Lake, Mount Wilson, San Jacinto Mountain, Santa Susana Pass and Santa Cruz Mountains. These include forms grading from the broad-leaved to the extreme narrow-leaved type. Seedlings grown from individual plants pollinated naturally in the field show segregation into phenotypes, some of which can be recognized as variant forms found in the vicinity of the original collection. Preliminary studies in the cytology of *Zauschneria* made by Dr. Donald A. Johansen seem to indicate that irregularities in chromosome distribution, aborted embryos and an apparently high percentage of pollen sterility are characteristic of at least some of the forms and suggest extensive natural hybridization. Since investigations in the cytology and genetics of *Zauschneria* give promise of aid in solving the problem of its phylogeny, it is planned to extend the studies in these fields during the coming year.

The present garden collection of 40 forms includes most of the general types found in the genus. These are used at the various transplant stations for testing effect of environmental influence on characters and for the making of direct comparisons. It is hoped that by increasing the number under observation and by close attention to their geographic distribution and genetic behavior some conclusions may be reached concerning the underlying factors which have brought the many variations of *Zauschneria* into existence.

STUDIES IN THE MADINÆ, BY H. M. HALL

This subtribe of the Compositæ was originally selected for investigation because of the large number of variations within some of the species, a condition essential for satisfactory studies in racial composition and species formation. The group is well suited to our needs also because of its restriction, almost entirely, to western North America, thus permitting of intensive field studies and of garden cultures. Finally, the species are for the most part annuals and therefore suited to development and illustration of methods in experimental taxonomy quite different from those employed with perennial plants.

Resumption of experimental studies in the Madinæ has been made possible through provision of glass-house and garden facilities at the new station near Stanford University. Fourteen species, now being grown at this location, each under several different combinations of soil, moisture and light, will afford material for studies in comparative morphology and in induced modification. A majority of the species do not flower until autumn, but as an example of results already obtained may be cited the case of *Hemizonia fasciculata* and its variety *ramosissima*. These have been supposed to differ only in features of the inflorescence, the capitulæ of the former being sessile in glomerules, those of the variety somewhat scattered on short peduncles. Even this difference is sometimes thought to result from variations in the habitat and to be associated with nutrition. Experimental tests, however, indicate that it represents a genetic separation. Plants of the two forms have been grown both in pot cultures and in the field, some so starved as to be only 2.5 to 3 dm. high, others so well nourished as to form bushes 10 to 12 dm. high and nearly as broad; yet in all the cultures, whether in sun or shade, the inflorescences are the same as those of the parents from which the seeds were taken. Experiments designed to disturb the nutritional relation through pruning, removal of central heads and other artificial means have likewise failed to modify this character, at first seemingly trivial but now known to be of a heritable nature.

As a by-product of these experiments an additional criterion was discovered for separation of the two forms. This has to do with mode of branching of the main stems. In cultures of the *fasciculata* type the terminal bud forms an inflorescence at an early stage, and the plant therefore becomes widely branched from near the base; in *ramosissima* the central shaft becomes much longer before a terminal bud is formed and in consequence the lateral branches continue further up the stem. Whether or not this habital character is always correlated with that of the inflorescence can be determined only after further field studies followed by additional experiments.

Particular attention is now being given to effect of climatic conditions upon formation of fertile central akenes in certain species of *Hemizonia* and the correlation of this character with presence or absence of pappus and of trichomes. Preliminary experiments indicate that at least the pappus character may be controlled through manipulation of the metabolism. If this is confirmed it will almost certainly open up the way to control of the other features mentioned.

Field studies in *Hemizonia*, section *Calycadenia*, are bringing to light so many intermediate forms that it may soon be possible to demonstrate nearly continuous phyletic lines that include species heretofore supposed to be widely separated. Since these plants are of small size and easy of culture they are being assembled to test the nature of their differences and to throw light upon evolutionary processes in a group where interpolations can be safely made in an almost continuous record.

CONTINUATION OF EXPERIMENTS ON HAPLOPAPPUS, BY H. M. HALL

When the taxonomic monograph on this genus was published in 1928, many forms could not be satisfactorily classified in the absence of experimental evidence as to nature of the involved characters. As a result of transplant operations evidence is now at hand for the placing of some of these variations. For example, it was noted that the taxonomic type of *Haplopappus squarrosus*, of section *Hazardia*, came from near the sea and was generally considered as only the maritime modification of a much more common form of interior valleys. But by growing the two side by side for four years, not only were the observed differences found to be permanent but other fixed differentiating criteria were discovered, notably a much darker pappus in flowers of the interior form. As a result of these experiments it is now possible to recognize these forms as distinct subspecies and to classify their characters into two groups—the genetically fixed and the ecologically modified. Similar experiments have confirmed the disposal of *stenolepis* and *obtusus* as subspecies of *H. squarrosus* and demonstrated the presence within *obtusus* of two races differing only by the presence or absence of a short pubescence on the involucres.

Quite different are the characters used separating "*Isocoma decumbens*" from *Haplopappus venetus vernonioides*, under which it was listed in the monograph as a minor variation. This was originally separated only on basis of its decumbent habit. Carefully checked plants of the decumbent form were grown at a transplant station under better soil conditions than those of its native habitat. Here, after three years, the plants are as rigidly erect as those of the common *vernonioides* type, some of which are also growing in this transplant area and are thus available for direct comparison.

Because of interest centering around the species of *Hazardia* and *Isocoma*, transplants are being assembled at the main station of as many as possible of the ecotypes of the two principal species, *Haplopappus squarrosus* and *H. venetus*. These collections permit direct comparison, under most favorable conditions, of forms from various geographic areas and also the testing of criteria used in their classification. Incidentally, they provide living illustrations of species composition and are of much service for the interchange of views with visiting botanists concerning principles of botanical taxonomy.

DESERT INVESTIGATIONS

Under the Direction of Forrest Shreve

During the past year 14 investigators have worked at the Desert Laboratory for periods of 3 to 12 months, and 42 scientists have visited the laboratory from one to 10 days, familiarizing themselves with its work or with its natural environment. The activities have been almost wholly confined to laboratory investigations and to intensive field work on the grounds of the laboratory and in the adjacent region. Some general field work has been done within a radius of 300 miles of Tucson. No major additions have been made to buildings or equipment during the year. The rearrangement of the library and the distribution of a list of the journals which it contains has led to a greatly increased use of its volumes by workers in other local institutions.

There has recently been a great growth of public interest in cacti and other desert plants, which has brought many visitors and much correspondence to the Desert Laboratory. In a section of the garden adjacent to the laboratory office a representative collection of desert plants has been arranged and labeled for the information of visitors.

The principal investigations have been concerned with microclimatology and habitat conditions and with the water relations and mineral nutrition of plants. Work has also been carried out on animal material, with reference to the basic physiology of invertebrate forms, as well as to habitat distribution of small mammals.

INVESTIGATION OF HABITAT CONDITIONS ON THE GROUNDS OF THE DESERT LABORATORY

Work on the physical conditions in habitats of restricted area has been continued and extended, with particular reference to the grounds of the Desert Laboratory and adjacent areas. The investigation of the conditions in the open as contrasted with those in the shade of the dwarf tree *Parkinsonia* has been continued long enough to make possible a comparison of the differentiation of these habitats in the dry and wet seasons. The contrast between soil moisture conditions in sun and shade is consistently greater in the rainy seasons than in the dry ones, the difference sometimes being as great as 14 per cent for 2 to 6 days following a rain of more than 1 inch. The rates of evaporation from the white atmometer are very similar in sun and shade throughout the year, although the actual weekly losses are only one-third to one-half as great during the summer rainy period as during the two dry seasons.

The comparison of soil temperature conditions in the wet and dry periods shows a greater differentiation of sun and shade conditions in the former season than in the latter, with reference to maximum and minimum at both 3 and 12 inches. The departure of soil temperature from the temperature of the air is less in the rainy season than in the dry, except in the case of the maximum at 3 inches.

The lowest minimum air temperature recorded during the winter months was 27° F. At the same time the absolute minimum for the soil at a depth of 3 inches was 35° in the open and 38° under the *Parkinsonia* tree. On other cold nights the soil minimum in the open was from 10° to 14° above that of the air, and the minimum in the shade from 1° to 4° above that in the open. Since air temperatures below 25° F. are very infrequent it is evident that frost rarely injures the crowns of roots perennials and such superficial roots as those of the cacti, and that the plants growing under trees are somewhat better protected than those in the open.

Rainfall records are now being secured at eight stations on the grounds of the Desert Laboratory, the most widely separated ones being nearly two miles apart, and the greatest difference of elevation among them being 800 feet. The differences between the amounts of individual rains and of seasonal totals in this small area are surprisingly great, and have in some cases given rise to conspicuous differences in the behavior of the vegetation in the different sections of the grounds.

Commencing January 1, 1930, a detailed record is being kept of the time of appearance of leaves, flowers and other periodic phenomena in 10 common trees, shrubs and cacti. Six observational areas of 1 square meter, located in different situations, have been established for taking a biennial census of herbaceous plants after each of the rainy seasons. These phenological data will be of increasing value after a number of years, and their interpretation in connection with the records of climatic and soil conditions will be of importance.

THE CHARACTER AND EFFECTS OF DESERT PRECIPITATION

In all arid and semi-arid regions considerable scientific and practical importance attaches to the precise character of the rainfall and its seasonal and intraseasonal distribution, particularly with reference to the maintenance of soil moisture. A detailed analysis has been made of the 23-year record of rainfall at the Desert Laboratory in connection with planning further investigations of the relation between rainfall and the fluctuations of soil moisture.

The average number of rainy days per annum is 61.6, including days with only a trace of rain. The average number of days with a measurable fall is 44.6. The number of days with a fall of 1 inch or more is 2.3 per annum. On the basis of a single year's record of soil moisture, determined at three depths, a preliminary subdivision of rainfall has been made into: (*a*) light rains, less than 0.15 inch, which are without effect on soil moisture; (*b*) effective rains, between 0.16 inch and 0.75 inch which affect the soil moisture; and (*c*) torrential rains, more than 0.75 inch, which affect the moisture of the soil but to no greater extent than do the effective rains. When the mean annual rainfall, 12.34 inches, is subdivided into the above classes the amounts are: (*a*) 1.46 inches, (*b*) 6.42 inches, (*c*) 4.46 inches. The effective rainfall is only 52 per cent of the total. During the 23-year period there have been only 89 days with rains in class *c*, but they have yielded 36 per cent of the total precipitation of those years.

One of the most important aspects of rainfall for vegetation is its irregularity, and the consequent variation in the length of the rainless periods. The greatest annual total was 23.32, the lowest 5.84 inches, at the same time that the greatest single daily fall of rain was 5.01, approaching the lowest annual total. The rainfall of the summer period has fluctuated from 11.44 inches in 1908 to 1.85 in 1924, while that of the winter period has varied from 10.29 inches in 1905 to 0.22 inch in 1925. In the last 23 years there have been 14 periods of over 10 weeks without effective rainfall, the longest period being 141 days.

The irregularities of the rainfall are responsible for much of the desert character of the vegetation. It is important to know to what extent and precisely in what manner the soil serves as a reservoir, tending to stabilize the irregularities of the precipitation. This problem is given considerable complexity through differences in soil texture, slope, cover and presence or absence of hardpan, or caliche.

PENETRATION AND RUNOFF UNDER DESERT CONDITIONS, BY FORREST SHREVE AND T. D. MALLERY

Considerable attention has been given at the Desert Laboratory to the investigation of soil moisture, the seasonal course of its changes, and its differences, in dissimilar habitats and types of soil. Continued attention is being given to this group of problems, which is basic to the program of work on the water relations of plants. It is desirable that a more precise knowledge be obtained of the fate of the precipitation, based upon a study of runoff, soil evaporation, and percolation into the deeper layers of the soil.

A study of runoff and penetration has been begun during the year, with a view to determining the fate of the precipitation and the amounts of water available to the deep-rooted plants. For them the conditions are much more arid than the rainfall statistics for the region would indicate, owing to the losses by runoff and evaporation.

In 1929 a block of 141 cubic feet of flood-plain soil was encased in cement on four sides, in its original position and without disturbance of its structure. The bottom of the block was supported by heavy timbers, and appropriate provision was made for measurement of the rainfall, the amount of water running off the surface and the amount penetrating the 30 inches of encased soil. In the exceptionally heavy rain of September 24, 1929, considerable damage was done to the cellar which gives access to the bottom of the block of soil. In the spring of 1930 this damage was repaired, and cement walls added to the entrance to the cellar. The late winter and early summer rains have given an opportunity to make readings and to test the operation of the appliance, which is designated a "lysimeter," although not primarily intended for the study of leaching. The object in the construction of the lysimeter is to ascertain all of the conditions which determine the variations in the amount of runoff, such as amount of rainfall, duration of rains and existing moisture content of the soil, as well as to measure the amount of percolation and to determine the conditions influencing it. The moisture content of the soil in the lysimeter can be followed closely by samples taken just outside it.

Following the close of the winter rains a series of samples taken at depths of 15, 50, 100, 150, 200, and 300 cm. showed a progressive increase of soil moisture with depth down to the 200-cm. level. The samples at 300 cm., however, showed a much lower moisture content, indicating that a period of 13 weeks since the first of the winter rains had not sufficed for penetration of water to the 300-cm. level. Since the installation of the lysimeter there has been no percolation of water through the encased soil, although there have been four rains of more than 1 inch. The runoff has varied from 74 per cent of the total fall, for a rain of 1.08 inch, to 4 per cent, for a rain of 0.11 inch falling three days after a heavy rain.

The determination of the gradient of change in soil moisture through the first 3 meters made it possible to estimate closely that the first 3 cubic meters underlying a square meter of surface contained 526 liters of water. This is the equivalent of 52.6 mm. of rain, which is 19 per cent of the mean annual precipitation. In the 4 months preceding the sampling, however, there had fallen only 47 mm. When allowance is made for runoff and evaporation, it is clear that the first 3 meters of soil contained water which had in large part fallen more than 4 months previously. This is not only additional indication of the high water-retaining power of the alluvial clay, but taken in connection with the reversal in the gradient of moisture content indicates the slowness of penetration.

The underground water of the valleys of southern Arizona is largely derived from the runoff of the upper portions of the drainage areas, and is not to be thought of as replenished at any one locality by the rainfall of that locality.

RELATION OF CALICHE TO SOIL MOISTURE CONDITIONS, BY EDITH B. SHREVE

In continuation of work previously done at the Desert Laboratory[1] on the physical properties of calcareous hardpan, or caliche, with particular reference to its rôle in movements of moisture, it has now been found that layers of this material act as a semipermeable membrane. The experimental evidence was secured with hard layers of caliche about 1 cm. in thickness, and with the use of cane-sugar solutions. An osmometer was made by sealing a piece of caliche into a glass funnel, filling the funnel with 0.5M cane-sugar solution and placing the large end in water. A tube was connected to the small end of the funnel and bent at a right angle to prevent more than 10 cm. pressure of sugar solution developing. With this arrangement the osmometer continues to pump water indefinitely.

Work is being done to determine whether or not the semipermeable property of caliche acts in natural soils to bring water from lower to higher levels. Soil samples are being taken at different times of the year in order to determine whether the difference in the concentrations of the soil solutions above and below the caliche layers is ever large enough to cause an upward movement of water that can not be accounted for by capillarity of the same soil in the absence of caliche.

A COMPARISON OF RATES OF EVAPORATION FROM DIFFERENT TYPES OF SURFACE IN RELATION TO CLIMATIC COMPONENTS, BY FORREST SHREVE AND M. FRAPS

The immediate object of this study is the comparison of the Livingston atmometer with a free water surface as measures of the evaporating power of the air. Complete records of the relative humidity, temperature, wind velocity, and radiant energy are taken in graphic form simultaneously with the measurements of evaporation.

The recording atmometers used in connection with tests of the atmometer as an instrument for the measurement of sunshine intensity are used in this investigation. Measurement of water evaporated from free surfaces is made by means of burettes from which water is automatically drawn as it is evaporated. The rates of evaporation from the two surfaces will be related to the graphic records of the several components influencing the rate of evaporation. It will be necessary to obtain data over a wide range of changing environmental conditions and combinations of the several factors involved in order to throw light on the degree of free response shown by the two types of surfaces.

A projected phase of this work is a comparison of the modes of response of mesomorphic and xeromorphic plants to the changing environmental components which determine the rate of evaporation in a purely physical system. The same type of recording apparatus used with the atmometers will be modified for the measurement of the transpiration rates. It is hoped that such an investigation may be of value in defining the limits within which the two types of plants respond (in transpirational water loss) as approximately "free" surfaces, and those limits within which physiological regulation is operative.

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[1] See Year Book No. 27, p. 198.

On the Measurement of Total Solar Radiation, by M. Fraps

A simple means of constantly recording the intensity of total solar radiation would prove of value in many phases of ecological and physiological investigation. No instrument of demonstrated accuracy over a wide range of atmospheric conditions, and of the desired simplicity, is at present available. With a view toward fulfilling these conditions, tests are now under way on the radioatmometer due to Livingston and the differential telethermograph described by Briggs, and previously used by Briggs and Shantz in connection with work on the water balance of plants. A Marvin pyrheliometer is used for measurement of the absolute intensity of radiation. Results will also be compared with the recording radiometer installed by Petit at the Desert Sanatorium and Research Institute of Southern Arizona.

Records of relative humidity, temperature, wind velocity and evaporating power of the air as measured by the atmometer are obtained simultaneously with the records of the radioatmometer and the differential telethermograph. It will thus be possible to relate any divergence of the latter two instruments in the measurement of solar radiation to the operative climatic factor of factors.

Continuous atmometer records, for both black and white atmometers, are obtained in the form of dots marked on a continuously moving record sheet. Each dot represents the evaporation of a constant weight of water. A similar line of dots records wind movement on the same sheet.

Investigations on the Water Relations and the Drouth Resistance of Desert Plants, by H. Walter

On the basis of his earlier investigations in Europe, the author has shown that the osmotic strength of the cell sap serves as an indicator of the hydration of the protoplasm. Upon the latter depends the course of all of the physiological functions of the plant, such as growth, photosynthesis and respiration. Therefore, the determination of the osmotic values of the sap of a plant serves as a basis for the understanding of all aspects of its water relations.

During the course of six months residence at the Desert Laboratory, the osmotic values were determined for a number of the characteristic plants of the desert vegetation, as well as for plants in the evergreen oak region and the mountain forests of the vicinity. During the period from October 1929 to April 1930, a total of over 1000 determinations of osmotic value were made. The methods used were the same that have been employed by the author in previous investigations. The results may be briefly summarized as follows:

1. For each species of plant there are definite and characteristic minimum, optimum and maximum osmotic values. The osmotic value is lowest during the intensive period of growth, and then in the fully developed leaves reaches a higher value which may be regarded as the optimum one. Under unfavorable conditions of water supply the concentration of the cell sap rises still higher. When a rather definite maximum value is exceeded

the leaves die. Plants of the same ecological type are characterized by similar osmotic values and similar relations between the critical points.

2. The amount of the osmotic value depends upon external conditions. On making a comparison of plants of the same species growing in different habitats the osmotic value is found to give the best index to the collective water relations under which each of the individuals is living.

3. In the investigations of drought resistance it is necessary to distinguish between the drought resistance of the plant as a whole and that of the leaves. Only the latter has been taken into consideration in the present work. The drought resistance of the leaves of a plant varies directly with the maximum osmotic value and with the osmotic inertia of the plant. The latter falls with increasing intensity of transpiration and rises with the capacity for intake of water and the metabolic use of water.

4. Close relationships exist between growth and the imbibitional state of the protoplasm, which is indicated by the height of the osmotic value. The lower the osmotic value the more intensive is the growth.

5. From the statements made in paragraph 4 it follows conversely that under favorable conditions for growth, the osmotic value is relatively low. Accordingly clear relationships are found between the distribution of a plant species and the osmotic value of its sap. In the center of the distributional area of a species, the osmotic value is always relatively low. On proceeding from the center toward the distributional limits it gradually increases and finally reaches its maximum value. This holds true for distributional limits controlled by water relations as well as for those determined by temperature conditions.

6. The anatomical and morphological structure of the plant does not depend directly upon the external conditions, but is determined by the imbibitional state of the protoplasm. Consequently a direct relation between the structure of the leaves and the osmotic value can be demonstrated. It appears probable that the increase in osmotic value is correlated with the appearance of the xeromorphic type of leaves, as in *Encelia farinosa,* a plant which also possesses mesomorphic leaves. The barrel cactus, *Ferocactus wislizeni,* very commonly exhibits an asymmetry of form, which is accompanied by a corresponding asymmetry in the distribution of osmotic values in its tissues.

RELATION BETWEEN OSMOTIC VALUE OF LEAF CELL-SAP AND SOIL MOISTURE CONTENT IN COVILLEA TRIDENTATA, BY H. WALTER AND T. D. MALLERY

A series of determinations of the osmotic value of the cell-sap of the leaves of *Covillea tridentata* and of soil moisture content has been started for the purpose of studying the changes in each and the relationship existing between them throughout the normally arid foresummer and the period of summer rains. Five *Covillea* bushes, each growing under very different conditions of moisture supply, were selected for this experiment.

A representative leaf sample is taken from each plant about every two weeks, or as weather conditions dictate, and at the same time duplicate soil samples are taken one-half meter from the crown of each plant and 15 cm.

below the soil surface. The cryoscopic method is used in determining the cell-sap concentration.

Only tentative conclusions can be reached from the data secured thus far. Apparently there is little direct correlation between the osmotic value of the cell-sap of the leaves and the moisture content of the soil, since soils containing 5.2 per cent and 14.92 per cent moisture have been found supporting plants whose leaf juices have osmotic values of 36.3 and 36.6 atmospheres respectively. The highest moisture content found was 29.8 per cent for soil around a copiously irrigated plant. This plant had leaf sap with an osmotic value of 34.5 atmospheres. It may be noted, however, that the plant with the highest concentration of the leaf sap found thus far, 41.6 atmospheres, was growing in soil with the lowest moisture content, 4.8 per cent.

The osmotic value of the cell sap of the leaves of a plant is believed to give an index of the water conditions surrounding the plant. The soil moisture content is only one of these conditions. Obviously such factors as root development, transpiring surface, depth and volume of the soil reached by the plant roots, soil type, temperature, humidity and many other conditions must be considered. A close correlation between soil moisture content and osmotic pressure of the leaf cell sap can not, therefore, be expected.

EFFECTS OF MINERAL SALTS UPON TRANSPIRATION AND WATER REQUIREMENT OF THE COTTON PLANT, BY BERNARD S. MEYER

This study dealt with the effects of several concentrations of certain mineral salts, applied individually, upon the transpiration and water requirement of cotton plants growing in a natural soil of low soluble salt content. The soil was maintained at a water content of 10 per cent, its determined moisture equivalent being 8 per cent.

The salts employed for the transpiration experiment were sodium chloride, sodium nitrate, potassium chloride, potassium nitrate, calcium chloride and calcium nitrate. The first four were applied to the soil in concentrations of 0.025, 0.05, 0.1, 0.2, and 0.4 per cent of the dry weight of the soil; with the calcium salts an additional concentration of 0.8 per cent was used. For four-day periods addition of any of these salts in all the concentrations employed, with the exception of the two lowest concentrations of potassium nitrate, resulted in a decrease in transpiration as compared with plants growing in the soil to which no salt was added. Transpiration progressively decreased in amount with progressive increases in the concentration of any of these salts in the soil. The results were essentially the same, whether transpiration was calculated on the basis of leaf area, fresh weight of the top, or dry weight of the top. It is clear that the concentrations of salts employed with reference to the soil conditions used lie in the range where osmotic effects predominate over specific ionic effects. Sodium chloride in concentrations of 0.0125, 0.025, and 0.05 per cent of the dry weight of the soil, and calcium chloride in concentrations of 0.0125, 0.025, 0.05, 0.1, and 0.2 per cent of the dry weight of the soil, were used in the water requirement study. Cotton plants were allowed to grow under these treatments for 50 days, the usual technique of water requirement studies being followed. The water requirement of the plants treated with sodium chloride decreased progressively with increased concentration of this salt in the soil. The two lowest concentrations of calcium chloride employed resulted in an increased water requirement, beyond that concentration the water requirement decreased progressively with increase in the concentration of calcium chloride in the soil. Shifting the basis of calculation to the fresh weight basis instead of the dry weight basis did not alter the general trend of the results.

It was also found that a progressive increase in the concentration of sodium chloride or calcium chloride in the soil resulted in a progressive increase in the final water content of the tops (leaves and stems) of the cotton plants.

INVESTIGATION INTO THE CAUSES OF VARIATIONS IN THE TRANSPIRATION RATES OF DESERT PERENNIALS, BY EDITH B. SHREVE

Work has been continued on the effect of osmosis on the rate of evaporation from a wet membrane. The investigation is planned with the hope of discovering a physical basis for the check which occurs in the daily march of transpiration rate in certain desert plants during the arid seasons.

The greater part of the year has been spent on the improvement of methods. A form of apparatus has been designed which provides a working model of the physical mechanism of intake, transfer and loss of water of the plant, reduced to its simplest terms. It consists of an osmometer connected by capillary tubing to an evaporimeter. It is separable at two places, so that rate of evaporation and rate of osmosis can be measured separately. When the three parts are connected, the rate of evaporation opposed by an osmotic solution can be measured. The interior of the apparatus is entirely of glass. The appearance of air bubbles can be detected in every part. The two connections are made by means of large cone and socket joints which are supplied with cups for mercury seals. The whole is mounted so that it can be placed on a sensitive balance, thus making it possible to compare loss of water by weight with the amount of intake from the osmometer, as shown by a mercury indicator in the capillary tubing.

The work is still in the preliminary stages, for great care has to be taken with calibration, regulation of temperature and humidity, and construction of membranes. An extensive investigation is planned for the use of various kinds of membranes, various temperature and humidity combinations and various solutions, culminating in the use of natural plant juices under normal environmental conditions. For the present, the work will be confined to the use of potassium ferrocyanide membranes in the osmometer, celloidin membranes on the evaporating surface and cane-sugar solutions in the osmometer at a constant temperature of 25° C. and 25 per cent humidity.

Thus far a few experiments which have been performed with both 0.5M and 0.2M cane-sugar solutions show the following: When the evaporimeter is separated from the osmometer, and is thus obtaining water freely, there is agreement between the loss by weight and the amount entering, as calculated from the movement of the mercury bubble. When the evaporimeter is connected to the osmometer and the entrance of water is thus opposed by the osmotic solution, the evaporimeter, for a time, loses more than it obtains from the solution. However, the loss by weight is less than the loss would be under identical conditions of temperature and humidity for the same period if the evaporimeter were drawing water freely. After a time the intake ceases altogether and at length the system is broken by the entrance of air through the membrane of the evaporation surface. For the same membranes the amount of decrease in the rate of evaporation and of the rate of entrance of water from the osmometer depends in some way upon the strength of the solution in the osmometer and upon the rate of evaporation from the evaporimeter. It is hoped that experiments with the apparatus in its present form will show quantitative relationships. The length of time evaporation will continue under the opposition of the osmotic solution depends upon the size of the pores of the membrane and of the evaporimeter and probably upon other factors as well.

The apparatus has been tested carefully and the results already confirmed show definitely that under the above conditions the rate of evaporation from a wet membrane is decreased when opposed by an osmotic solution separated from it by another semipermeable membrane. The rate at which the evaporimeter obtains water from the osmotic cell is negatively accelerated until the rate becomes zero.

INVESTIGATIONS ON THE TRANSPIRATION OF DESERT PLANTS, BY EDUARD SCHRATZ

The experiments on the transpiration of desert plants which were begun in the spring of 1929 (see Year Book for 1928–29, p. 188) were continued through the summer rainy season until the end of my stay at the Desert Laboratory. The data obtained from these experiments have been prepared for publication, and their main results may be summarized as follows:

The water loss was studied in several species by cutting small shoots, sealing the cut ends and weighing them on a chainomatic balance at intervals of 1 to 2 minutes for a short period. It is clear that such a method will not give a knowledge of the normal transpiration of the shoots in place, especially if weighing periods as great as 15 minutes or longer are used. Under the extremely arid conditions of the desert the water losses from cut shoots decrease rapidly from a time shortly after the first reading, obtained immediately after cutting. The degree of this decrease in water loss is dependent first upon the absolute rate of the transpiration at the time of the experiment, the plants with high transpiration rate showing the most marked decrease. Furthermore, the decrease is dependent in degree and rate upon the morphological structure and grade of succulence of the plant. A rather close relation exists, however, between the values calculated from the first short period reading and those of later periods. The figures obtained from the earliest readings may be used for purely comparative studies.

The study of absolute transpiration values was undertaken by the bell jar method, the use of which permitted the simultaneous investigation of several plants, growing in place, and the repetition of the readings several times each day. Since it was so arranged that no change of importance took place in the temperature or relative humidity inside the bell jar, absolute values for the transpiration rate and its daily march were obtained. This method was used mainly for the comparative study of the transpiration from different types of plants, including especially the xeromorphic plants and mesomorphic annuals of the rainy season. These experiments should form a contribution to the question as to whether or not xeromorphs are characterized by a limited water loss or whether they show a higher rate of transpiration, as many recent authors believe.

The experiments, repeated under different conditions (as climate and water supply in the soil) proved that different species do not keep the same relation in their transpiration rate throughout the season. Under certain conditions the mesomorphic plants have a much higher transpiration than xeromorphic plants show at that time. Under different conditions, however, this relation may be reversed. In general it is true that the mesomorphic structures lose more water when there is a plentiful supply of water. When conditions are less favorable, the xeromorphs show the higher transpiration rate.

From the physical point of view, however, such results are not suitable for the decision as to which plant structure is able to offer higher resistance to the evaporating power of the air. Under extremely dry conditions the mesomorphic plants suffered, due to their less developed root system and a higher water deficit, brought about by the limited water supply, not because of the lesser resistance offered by the leaf structure. In every case in which it was possible for the plants to balance their water loss by water intake the mesomorphic plants showed the higher water loss.

GERMINATION AND ESTABLISHMENT OF COVILLEA, BY E. H. RUNYON

Experimental plats of 100 square meters established on the grounds of the Desert Laboratory for investigation of seeding habits of *Covillea* have been followed throughout the year (see Year Book No. 28, p. 187). Since the establishment of the areas in September 1928, no germinations have occurred on the undisturbed control areas. In the area from which all mature bushes were removed and on which the surface soil was overturned to a depth of 10 cm. there have appeared 91 seedlings. On an area from which the mature bushes were not removed, but on which the surface was overturned in the same manner, there have appeared 49 seedlings. On an area which was cleared and raked, and on another area which was cleared and covered with soil from another locality, there have appeared 10 seedlings each. Two uncleared areas which were raked and covered respectively have no seedlings. On an area which was uncleared and covered with fresh soil there are 4 seedlings. These figures show the natural reproduction to be strongly influenced by surface soil conditions, and to some extent by the removal of adult plants. The time of appearance of seedlings in relation to seasonal conditions and their precise location in the areas is being closely followed. Further efforts are being made to analyze the conditions to which the differences in reproduction may be due.

The seed dormancy caused by pericarp characters in *Covillea* has been found to be general in freshly gathered seeds and to be considerably reduced in seeds which have been stored for 12 months. Germination tests have been made with successive crops of seeds from some 25 individual bushes, revealing a difference in the capacity for germination in seeds from different bushes. The proportion of fruitlets containing viable seeds is frequently small, varying from 15 to 85 per cent, and being fairly characteristic for each plant. An investigation of the fruits of two of these bushes reveals a degeneration of the embryos which appears to be due to a bacterial parasite.

Further work has been done on the water extract from fruits and leaves of *Covillea*. Although in laboratory tests this extract has been found to inhibit germination, conclusive evidence has not yet been secured as to the possibility of its playing a rôle in the natural reproduction of the plant.

Work on the water content of the leaves of *Covillea* (see Year Book No. 28, p. 188) has been continued, in connection with which a study is being made of the anatomical difference between the large leaves found on well-watered plants and the small ones characteristic of the arid seasons. The object of this investigation is the determination of the condition and behavior of the leaves at the maximum and minimum water contents, the relation of the water deficit of the leaf to that of the stem, and the influence of water content on transpiration. It is believed that the results will give important evidence as to the elasticity in water requirement of non-succulent desert perennials.

New Methods for the Measurement of Transpiration, by M. Fraps and Forrest Shreve

The measurement of transpiration in physiological and ecological investigations involves a number of basic conditions which are not readily satisfied by the gravimetric method ordinarily employed. The most important consideration is that the measurement of transpiration be made with the least possible alteration of environmental conditions obtaining at the time of the determination. Measurements should be based on the transpiration of small quantities of material in order that quantitative results may be the more readily obtained. The method, finally, should be simple enough to permit rapid and frequent determinations.

Two methods for the measurement of small amounts of water vapor in the atmosphere and the application of these methods to the accurate determination of transpiration are now being investigated. Although neither method has been perfected, enough has been done to indicate the possibilities of the principles involved. A brief description of the two methods follows.

1. The volumetric determination of water vapor. The method depends upon the measurement of the amount of water vapor absorbed from a known volume of gas. Several different forms of apparatus have been used. The Carpenter modification of the Haldane apparatus has given very good results, though the amount of water vapor which can be measured in this apparatus is limited by the short length of the burette which is available. With a simple form of carbon dioxide absorption pipette, readings have been obtained within the limits of accuracy of the apparatus. Absorption, however, is slow with this form of pipette; other forms of pipettes designed

to bring the gas into more intimate contact with the absorption solution are now being tested. Sulphuric acid has been used as the absorption medium; an all-glass absorption pipette must therefore be used. The method requires only a very small quantity of water vapor (or of collected gas) for an analysis. Not more than 500 ml. of air need be passed over the transpiring material for establishing constant rate of flow, washing of connecting tubes, and collection of the sample from which several 40 ml. volumes may be drawn for analysis.

The use of not more than a few square centimeters of material for an accurate determination of transpiration should lead to a far more accurate relation of transpiration to other physiological or morphological analyses which are dependent for measurement on removal of leaves from the plant.

2. Determination of water vapor by the measurement of saturation deficit. A stream of air at known and constant velocity is passed through a chamber so designed that the air is completely saturated or quantitatively approaches saturation. The amount of water required to saturate the air is read directly from a volumetrically calibrated capillary tube. The continuous observation of the measuring gage makes possible a close check on the amount of water passing into the saturation chamber in a relatively short period of time. The chamber in which saturation occurs must of course be maintained at a constant temperature.

Only a small amount of air need be drawn over the transpiring material for a determination of the amount of water vapor in the air stream plus that due to transpiration. Air drawn directly into the saturation chamber gives the amount of vapor in the stream before it has passed over the transpiring material. The difference between the two values, with due correction and reduction, gives the amount of water vapor evolved by the transpiring material per unit volume of air. The method requires very little material and is rapid in comparison with the usual gravimetric procedure; it does not approach the volumetric apparatus, however, in point of sensitiveness.

FIXED SCALE MANOMETRIC APPARATUS, BY M. FRAPS

In a recent paper, manometric apparatus was described for the measurement of energy exchange reactions in *Planaria* and similar free motile forms. Further work with the manometric method has led to a number of improvements which have proven to be of considerable value. These are described in a paper to appear shortly in Physiological Zoology, supplementing the description of apparatus which has been reported in the same journal.

The apparatus described as *fixed scale manometers* is so designed that the chambers containing the experimental material are shaken continuously during the course of an experiment. The manometer gages are permanently fixed within the constant temperature bath and may therefore be read at any time without stopping the regularly oscillating chambers. A further improvement in the apparatus lies in provision for aeration of chambers with experimental gas mixtures at any time during the course of experiments. The procedure has proved particularly convenient in aeration of material under conditions of anaerobiosis, or in the change of experimental atmospheres where a very slight contamination of atmosphere leads to faulty results.

Metal has been used extensively in the construction of the apparatus. Some care must be exercised in the use of metal in the presence of various gases, particularly oxygen. Stopcocks have been eliminated in favor of needle valves; the latter, in addition to being absolutely leak-proof if properly made, are more convenient and require much less space than do glass stopcocks.

The point should be emphasized that in the measurement of energy exchange reactions in free motile forms such as *Planaria* by manometric methods, other considerations than the actual sensitivity of pressure determination very largely control the constancy of results. In *Planaria*, for example, motor activity is stimulated quite as much by bringing a regularly oscillating chamber to a stop as by setting into motion chambers which have remained stationary for some time. During continuous shaking, on the other hand, motor activity remains relatively low. With the usual form of manometer, "discontinuous" shaking of chambers is necessary in order that the gages may be read; the shorter the time interval between readings, therefore, the greater is the consequent stimulation to which the material is subjected.

It is, of course, absolutely essential in using manometers that accurate control over temperature and barometric fluctuations be maintained at all times. In the paper already mentioned these factors have been considered with special reference to conditions obtaining at the Desert Laboratory.

ECOLOGY

INVESTIGATIONS UNDER THE DIRECTION OF FREDERIC E. CLEMENTS

CALORIMETRY, BY FRANCES LONG, EMMETT MARTIN AND GEORGE MERIDETH

Calorimetric studies have been continued through the year in the experimental gardens at the Alpine Laboratory on Pikes Peak and at Santa Barbara, with especial reference to various factors or factor complexes. A wide range of material has been passed in review, with results such as are indicated in the following tables; for the sake of brevity only a small number of the species employed is given in each case.

The highest value at the Summit is approximately twice as great as the lowest, the rank of *Oreoxis* probably being due to the presence of the oil-tubes characteristic of the *Apiaceæ*. The lowest values are evidently related in some way to the presence of a high ash-content. Three of the four species at the lower station yielded higher values in correspondence with the less rigorous climate, in spite of a greater theoretic absorption of radiant energy by the atmosphere.

There is a regular and often considerable difference in the number of calories per gram of dry matter in favor of the sun form, but this is far less than the difference in the light intensities, probably in consequence of the low utilization of incident energy in photosynthesis. The range between the high and low species is nearly twice as great in the shade as in the sun. The ash-content follows the usual rule in being larger in the shade than in the sun, as well as in bearing an inverse relation to the total energy.

The plants of the first two species gave higher values in the soil with only natural rainfall than in the wet or saturated soil, by contrast with the third in which the wet end of the transect was three times more favorable. However, the optimum for *Helianthus* was 622,000 calories in moist soil.

TABLE 1—*Total energy of species in the same habitat*

Species	Wt. of plant		Water	Ash	Calories per gm. dry wt.	Calories per plant
	Wet	Dry				
Summit, Pikes Peak 14,000 ft.:	*gm.*	*gm.*	*p. ct.*	*p. ct.*		
Oreoxis humilis	1.91	....	....	8.5	4445.7	555.7
Gentiana frigida	9.70	1.54	81.5	8.3	4315.6	6646.0
Mertensia alpina	.38	.12	70.3	7.1	4159.9	499.2
Saxifraga chrysantha	.10	.03	69.2	17.9	3974.3	119.2
Lusula spicata	.38	.12	69.2	19.2	3649.2	426.9
Festuca brachyphylla	7.65	2.50	67.3	25.6	3171.6	7929.0
Alsine baicalensis	....	....	74.2	48.9	2331.1	20513.6
Windy Point, 12,000 ft.:						
Gentiana frigida	1.43	.25	82.5	4.6	4691.9	1172.9
Saxifraga chrysantha	1.40	.32	76.6	5.1	4314.6	1380.6
Mertensia alpina	1.61	.32	80.6	9.2	4130.9	1321.8
Lusula spicata	1.26	.32	74.4	9.1	4089.2	1308.5

TABLE 2—*Total energy of sun and shade forms of the same species*

Species	Sun form		Shade form	
	Ash	Calories per gm.	Ash	Calories per gm.
	p. ct.		*p. ct.*	
Epilobium angustifolium	3.5	4401.2	6.0	3830.7
Mertensia sibirica	8.5	4190.4	13.4	3962.5
Smilacina stellata	7.3	4429.3	9.4	4159.6
Streptopus amplexifolius	8.4	4346.6	10.2	3742.6
Thalictrum fendleri	3.5	4552.1	8.2	4378.3

In a sun-shade transect of the latter species, the calories decreased gradually from 27,934 in the sun to 14,243 in the middle, and to 7473 in the deeper shade.

TABLE 3—*Relation of total energy to dry and wet soil*

Species	Dry soil	Wet soil
Helianthus annuus	267,546.5	187,588.3
Gilia capitata	53,149.4	40,761.3
Eschscholtzia californica	20,360.5	71,398.6

The most favorable situation in the competition bed 20 feet square yielded a value 17 times greater than the least favorable in terms of calories, 15 times in dry weight and 11 times in green weight.

TABLE 4—*Total energy of dominant and suppressed competitors*

Helianthus annuus	Wt. of plant		Water	Ash	Calories per plant
	Wet	Dry			
	gm.	*gm.*	*p. ct.*	*p. ct.*	
South margin	938.2	152.8	83.7	7.1	622,000
North margin	415.1	61.5	84.9	8.1	242,000
North suppressed	261.4	34.0	87 0	7.8	136,600
Center dominant	121 1	21.3	82.4	7.8	82,110
Center suppressed	83.1	9 8	85 8	8.0	36,757

The pyrheliometer was employed for determining the solar radiation for the three main stations at 6000, 8500, and 12,000 feet, but with the single instrument available the readings were not strictly comparable. The value increased approximately 5 per cent for each of the higher stations, indicating a fair degree of regularity with the altitude. In 1930 a pair of instruments was available for simultaneous measurements and was supplemented by photo-electric apparatus, spectro-photometer, selagraph and chemical methods of measuring light.

INSTRUMENTS AND METHODS, BY F. E. CLEMENTS AND G. W. GOLDSMITH

The first endeavor to organize ecology on the threefold basis of measurement, experiment and development was made in *Research Methods in Ecology* (1905), at a time when it was necessary to devise or adapt most of the instruments employed. During the quarter of a century that has elapsed, much progress has been made in adapting existing physical instruments and in designing new ones. However, the accounts of these are widely scattered, frequently in physical journals not accessible to ecological workers, especially to those in remote regions of great ecological opportunity. Even more serious has been the general lack of comparative tests in actual use of the various instruments for measuring a particular factor, with the consequent uncertainty as to the best one for the purpose or the relative merits of various types. Furthermore, it is obvious that needs and opportunities vary greatly and that the best instrument for a research laboratory with a staff of workers is often too elaborate and expensive for the individual student. In consequence, the present project is intended to make a comprehensive test of available instruments and methods through actual use under varying conditions, as well as to devise new ones where this is desirable or feasible. The ultimate purpose is to render investigations more and more accurate and comparable, and to hasten the day when ecology will partake in some degree of the objectivity of chemistry and physics.

The methods considered fall under several major heads: (1) habitat factors; (2) response in function and form, including adaptation; (3)

quadrat and other quantitative methods in the community; and (4) analysis of climax and succession. Intimately connected with these basic methods are those of bio-ecology and of paleo-ecology, which are undergoing separate treatment at the present time. The paramount need is for improved instrumental and phytometer procedure in the habitat and for more exact quantitative measures in climax and sere.

With respect to instruments, there are three major lines of approach, *viz*, the improvement of existing ones, the adaptation of physical instruments, and the devising of new ones or new types. Apart from the comparative tests of present instruments, the chief problem lies in adapting laboratory ones, especially in physics, to the field. This usually involves obtaining portability and ruggedness without undue sacrifice of delicacy and accuracy, qualities often directly opposed. The comparative tests are designed to determine the limitations of each instrument in these respects and its most profitable field of use alone or in conjunction with others, as well as its simplicity of operation and value in relation to cost. A further desideratum of great importance is the delivery of results in the form of standard units or ready conversion into physical units. The factors chiefly to be considered are the direct ones, namely, radiant energy, as well as light and heat separately; water, including holard, chresard and humidity, soil-air and solutes; but these necessarily involve adequate attention to the many indirect ones, such as rainfall, pressure, wind, evaporation, soil, acidity, etc.

Two new instruments have been developed and tested in use during the year. One of these is an evaporimeter in which simplicity, strength, portability, self-regulation and low cost have been combined to a degree probably to be found in no other instrument for this purpose. For the ecologist it bids fair to realize the ideal installation of an evaporimeter alongside each rain-gage. It has been designed by Stark and Whitfield,[1] and is briefly described by them as follows: "The instrument consists essentially of an evaporation pan with an adjustable rain overflow, and a sealed reservoir with an air intake and a water connection leading through a petcock into the pan."

The second is a photo-electric set-up containing an improved triode circuit in which the changing characteristics of the thermionic tube have no effect upon the readings of the photometer. The instrument is rugged, though not at the expense of accuracy or sensitiveness, and is completely adaptable to other types of cells. It permits the measurement of extreme ranges of light intensity from full sunlight to deep shade without the inconvenience of changing the battery voltage. Another feature is a regulating device by means of which it is possible to maintain the potential applied to the photo-electric cell at a constant value.

RAINFALL AND SUNSPOT CYCLES, BY F. E. CLEMENTS

The initial studies of the relation of vegetation to rainfall and sunspot cycles were begun in 1912 and have been continued more or less actively since that time.[2] This was assumed to be a strategic moment, as the sunspot minimum of 1913 was expected to approach the absolute minimum last recorded in 1810, which was attended by high precipitation. The minimum number proved to be 1 rather than zero, but was followed during the next year or two by the heaviest rainfall known for the West. This led to the further assumption that the succeeding maximum would be high since it closed the second double sunspot cycle, and that the rainfall deficit would be very great, in compensation for the excess of 1913–15. Both assumptions proved to be correct, the maximum being 104 spots, the highest for fifty years, and the accompanying drouth period of 2 to 4 years probably the worst ever experienced by the West. The minimum of 1923 was not exceptionally low, possibly in compensation for that of 1913, nor was the rainfall generally high, a result to be anticipated from the deficit of 1917.

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[1] *An Improved Evaporimeter,* Ecology, vol. 11, 288-292, 1930.

[2] *Plant Succession,* 1916.

The further employment of the double sunspot cycle as a basis of prediction indicated a maximum in 1928–29 with a sunspot number less than 80, the assumed lower limit in connection with a serious drouth period. The maximum fell in 1928 with a number of 76 spots and was not attended by a typical drouth period, though regional drouths of several months or more were fairly widespread. On the same basis, this relatively low maximum should be followed by a higher one in 1939–40, accompanied by general and protracted drouth; the intermediate minimum should be marked by more than normal precipitation. In this connection, it appears significant that Hann in 1908 by the use of the Brückner cycle of 35 years, approximately a triple sunspot cycle, forecast 1918 as a wet year and 1928 as a dry one.

The preliminary investigation of the possible relation between drouth periods and sunspot maxima[1] was made ten years ago upon the basis of the plus and minus departures of approximately 1300 stations in the West. The consistency of the results suggested the desirability of taking the complete record into account and over even a wider territory. In pursuance of this plan, new rainfall means to the end of 1927 have been computed for all states west of the Mississippi, as well as for Wisconsin, Illinois and Indiana, and the departures from the mean have been compiled in inches and percentages. In addition, the long records of major stations in the East are being employed and likewise the records of stations in western Canada and extra-tropical Mexico, in so far as these are available. Furthermore, the success of Browne and of Clayton in utilizing the 10-day means for the solar constant derived by Abbot has led to the study of the relation between monthly sunspot numbers and the corresponding rainfall.

While the immediate concern of this project is with rainfall and sunspot cycles in relation to climaxes and relicts, the problems of forest and range and their influence upon water supplies, it is evident that it has a direct bearing upon long-range prediction and consequently upon various phases of human ecology.

EXPERIMENTAL ADAPTATION, BY F. E. CLEMENTS, C. J. WHITFIELD, ORLIN BIDDULPH, J. L. GARDNER, BRUNO KLINGER AND O. K. STARK

To the series of climatic, edaphic and conversion gardens at the Alpine Laboratory and control gardens at Santa Barbara have been added two dune gardens on the shore at the latter station. One of these is located in a mobile area, constantly wind-swept and with a pure sandy soil very pervious in texture; the other lies in a protected hollow occupied by a dense consocies of *Lupinus albifrons*. These shrubs have been left about the denuded garden area for further protection; the soil contains much humus with the sand and is almost impervious, water standing on it for a considerable time. A dozen species of those grown in the control gardens, mostly annuals, were transplanted as seedlings to the two areas and watered until established. Survival was better in the mobile area, but dwarfing was more pronounced, even the sunflowers flowering at 3 to 4 inches. Several species were unable to endure the conditions in the denuded area, but most of them grew much better than in the wind-swept garden. The habit in general was that of the strand, the axis being shortened, the branches long and procumbent, and the leaves thicker.

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[1] *Drouth Periods and Climatic Cycles*, Ecology, vol. 2, 181–188, 1921.

The adaptation garden at Santa Barbara comprised the usual series for water, nutrients and light, but a row of 10 beds was added to the first in which protection against rain yielded drier conditions than in the normal row. Modification in the light series was greatly increased by replacing cloth tents by lath-houses with light intensities of 12 and 4 per cent. These permitted better circulation and were much more convenient in every respect. A new installation was designed for the purpose of determining the effect of different lengths of day under garden conditions. Dark boxes 4 feet in each dimension were utilized to cover the beds from afternoon until morning for such periods as to give a short-day exposure of 6 hours to one row and a medium-day exposure of 10 hours to the other, while the control row received full daylight, averaging about 14 hours for the season of growth. In all six species, flowering occurred first in the full-day row; it was about a week later in the medium-day row and still later in the short-day, but in none was it suppressed. The color of the leaves decreased in the same direction, from dark-green to yellow-green, the short-day plants being semi-etiolated. For such vigorous genera as *Clarkia* and *Verbesina*, growth was best in the full-day, while low delicate forms, such as *Nemophila insignis* and *Phacelia campanularia*, grew best in the medium-day row. The latter yielded the most striking modification, the plants in the medium-day being greatly suppressed, with very short nodes, fleshy stems, large leaves and elongated petioles forming definite rosettes. The short-day plants exhibited the same characteristics, but to a smaller degree. The form was almost exactly that of a typical strand plant, and suggests that more diffuse illumination may be a factor in the production of the latter.

In addition to the routine measurements, factor results and notes on the 30 species under the several conditions, the wet and dry weight and the total energy were determined for most of the species, especially those grown in all the series. Especial attention was paid to modifications in the number and distribution of the stomata, and in the 24-hour cycle of stomatal behavior. As a general rule, the number of stomata were closely correlated with the conditions for growth, decreasing per unit area as growth and expansion increased. In the case of light, however, and with certain species in the water and nutrient series, leaf expansion was greatest in median conditions, and the number of stomata greater at the two extremes. In some cases, the inverse relation did not hold between growth and number, indicating a more deep-seated modification of the meristem.

The chief advances in this field at the Alpine Laboratory have been in the expansion of the tent or box method of segregating factors and responses, and the further development of the phytometer technique. Because of the low stature of the plants concerned, the former has been centered in the alpine climax. Cloth shade-tents for reducing light-intensity have been employed as in the past, and these are supplemented by filter boxes provided with screens of known wave-length, red, green, blue, ultra-violet, infra-red, etc. In addition, shelter devices have been installed for determining the effect of wind and large evaporation pans with plant inserts in the endeavor to increase the humidity effectively. Likewise, in the attempt to manipulate the temperature and to increase or decrease the length of season, cold pits have been constructed by removing the sod to the root-depth, excavating a pit and packing it with snow, and then replacing the plant cover. Warm pits have been similarly constructed, after the manner of hot-beds.

The sealed phytometers comprise *Helianthus annuus*, *Mertensia sibirica*, and *Caltha leptosepala*, placed in batteries of six each in sun and shade in the five climatic gardens and in each of the four edaphic ones. The free phytometers number a dozen species, annual and perennial, some of the latter dating from the previous year; these are located in the water transect and in half-shade. Similar phytometers of *Helianthus*, *Triticum* and *Zea* are installed in the climatic gardens from plains to summit, primarily for the determination of total energy. The sealed phytometers are weighed at such successive intervals as to yield the forenoon, afternoon and night water-loss, the 24-hour loss, and the weekly loss. The stomatal cycle is likewise determined for the shorter intervals, together with the osmotic values for the cell-sap of the leaves. Stomatal numbers, wet and dry weight, and total energy are found at the end of each series and correlated with the factor values derived from the batteries of instruments.

EXPERIMENTAL MORPHOGENY AND REVERSION, BY F. E. CLEMENTS AND E. S. CLEMENTS

While a dozen genera are grown for various types of manipulation, attention has been focused during the past year chiefly upon *Plantago lanceolata*, and to less degree upon *Calendula officinalis* and *Campanula medium*. *Plantago* has been subjected chiefly to conditions producing overgrowth in the manipulation garden at Santa Barbara, but it has also been grown in the adaptation and competition series there, and as well in the shade and water transects at the Alpine Laboratory. In addition to the two original wild plants brought into cultivation in 1925, from which most of the new forms have arisen, wild individuals to the number of one to five have been introduced annually. Altogether, nearly a score of species of this genus have been grown under similar conditions, but so far only one or two others have produced terads. A consistent endeavor has been made to obtain selfed seed of all terads, and most of the forms under study at present are derived from such seed.

The number of different modifications produced is large and so far has increased with each year. Most of these appear with such suddenness as to warrant calling them mutations, but the large number of intermediates suggests that they belong in the extensive category of adaptations. The great majority of the terads are due to changes in inflorescence or flower, though the leaves also show marked differences in shape, width, color and hairiness. The most striking terads are those with involucres, compound spikes of various types, furcate spikes, long-pedicelled flowers, staminodes, or pistillate flowers alone. There are at least three intermediates between the latter and the normal perfect flower, indicating that the process is gradual and not saltatory. Modification has also operated upon the stature, dwarfs being frequent, the length of the style, the form and coloring of the bracts, hairiness and marking of the capsules, many of them of the order of specific distinctions.

The fixation of the terads has been traced in the progenies of selfed individuals, and in a number of cases has proved unexpectedly high. For the production of a particular terad, it rose as high as 50 per cent and for the process itself, involving two forms, it was as high as 85 to 100 per cent in the water series. There is further some preliminary evidence to indicate that the degree of fixation increases from year to year.

The first studies of reversion were made several years ago with vegetables, but they proved somewhat unsatisfactory, owing to lack of uniformity even in the cultivated garden. This difficulty has been avoided by the use of highly bred ornamentals, such as *Calendula officinalis* and *Campanula medium*. When these are grown from seed in the sterile garden, they become modified in one or at most two years into forms suggesting the wild originals.

ECOLOGIC AND TAXONOMIC ANALYSIS OF PENSTEMON, BY C. W. PENLAND AND D. D. KECK

This is a cooperative study of a large and polymorphic genus that is all but exclusively American. It exhibits two definite and extended centers of evolution, the Rocky Mountains and the Pacific Coast, thus lending itself readily to joint but regional study, both in field and garden. Approximately 50 species are now under cultivation in the main garden at Colorado and somewhat less in that at Santa Barbara. A few alpine and subalpine species were transplanted several years ago to the montane garden at the Alpine Laboratory and have slowly changed under the new conditions. A considerable number of plains species have been moved up into the same garden, and it is hoped to install all the species in the complete series of climatic gardens and some edaphic ones as rapidly as the material permits. A few California species have been tested in Colorado, but have nearly all been winter-killed. On the other hand, plains and mountain species have thrived at Santa Barbara, blooming several months earlier than normal and in the case of some, like *Penstemon cobaea*, attaining an unrivalled perfection of bloom.

Penstemon has also been employed in the attack upon the problem of hybridization in nature. While no natural hybrids have been found, with the probable exception of *P. parishi* in California and a form of *P. unilateralis* in Colorado, selfing has been carried on for several years in the hope of disclosing hybrid species. Unusually favorable conditions in the summer of 1929 resulted in several hundred selfs and crosses, the progeny of which should bloom this year. While it has become evident that many of the species can be crossed by hand, there is as yet no proof that any of the native species, with the exceptions noted above, are the result of hybridization. However, an additional test of the possibility of hybridization through insect agency is being carried out in Santa Barbara by planting the species in juxtaposition and cutting them back from time to time to produce almost continuous blossoming throughout the year.

MONOGRAPHS OF THE GRASSLAND CLIMAX, BY F. E. CLEMENTS, B. C. THARP AND A. G. VESTAL

During the past year field trips have been made through the six associations of the grassland formation, and resident studies have been carried on in three of them. The mixed prairie has received much attention, having been thrice traversed throughout its width along different transects. This has thrown new light upon its structure and has more clearly revealed the natural basis for its subdivision. It now appears to fall into six or eight major divisions or faciations, the exact number as well as the limits of certain ones being complicated by the effects of overgrazing. The proper basis for the subdivision of the faciation has been a more difficult task, since in more restricted areas, topography, soil and overgrazing combine to obscure the climatic pattern. As such climatic groups occupy localities rather than regions, they have been termed lociations. The method of recognizing faciations and lociations is being worked out in detail on a basis as objective as possible, with the purpose of giving a much more complete and definite character to the several associations.

The subclimax prairie of the central Mississippi Valley has been the object of especial interest for the past two summers, during which it has been traversed in several directions. As a consequence, it now appears probable that the true prairie extends further to the eastward than formerly thought, its eastern portion having been much disguised by the rapid incursion of the coarser Andropogons during the period of settlement, with the consequent reduction of the typical mid-grasses. This indicates that the tall-grasses are less dependable as indicators of the subclimax prairie, and that more emphasis must be placed upon the relative position and extent of prairie and forest, and upon the type of soil.

The further study of the coastal prairie of Texas has been directed chiefly to the recognition of faciations, the relation of postoak savannah and mesquite to the grassland, and the composition and extent of the vernal societies. Because of the high rainfall, societies are exceptionally well developed in this association, and hence it affords an unusual opportunity for the further analysis of the society and the distinction of the various kinds. The coastal prairie also furnishes a unique field for the study of the present-day origin of subclimax prairie as a consequence of fire.

CLIMAX AND CLIMATE, BY F. E. CLEMENTS AND E. S. CLEMENTS

In the course of the field work of the past two years the continent has been crossed four times by motor, and the forests of the East have been scrutinized from Canada to the Gulf of Mexico. The chief object has been to trace on the ground and in greater detail the interrelations of climaxes and climates, but this has necessarily involved many related questions. First among these is that of relicts and their significance in deciphering the movements of climaxes under the compulsion of climatic shifts and in suggesting the present secular trend. The correct interpretation of such evidence rests upon a proper understanding of the community bond within each formation and association, and this in turn hinges upon a comparative knowledge of their development and structure. From these is fashioned the key that unlocks the recent past by revealing the dynamic relations of preclimax and postclimax to the climax and climate in existence and by assigning to subclimaxes their proper secondary relation.

Each climax yields more or less evidence of climatic shifting throughout its extent, but this is most plentiful and eloquent in the ecotone where it meets adjacent climaxes. Ecotones thus serve as the major records of past movements and constitute the regions of potential movement for the future. They constitute a dynamic interlacing pattern throughout the vegetation of the North American continent, which has its counterpart in Eurasia, and furnish by far the best means of delimiting climatic shiftings and of coordinating them in space and time.

Subclimaxes often inject a disturbing note into the climatic harmony of contiguous formations, and it becomes imperative to recognize them as such and then to determine the cause of each and its real nature. The great majority of them are due to disturbances wrought by man through fire, lumbering, grazing, etc., best illustrated by the various "jack-pine" forests and the short-grass plains. Others, like the coastal swamps of Texas, are likewise seral in nature, but they are the subfinal stage in a primary sere. Much less frequent but more significant are such communities as the subclimax prairie, which represents a relict climax, now maintaining its own against the climatic forest by virtue of its occupation and competition.

Of the divisions of the association, the faciation is climatic, the effects of the more recent climatic migrations being discernible in its structure, while the lociation is in part edaphic. The nature of societies is much more variable; in grassland they are climatic in a large degree, though more or less affected by the competition of the dominants. In forest, competition with resulting dominance and subordination appears to be the ruling process, though it is evident that the societies respond to a climatic control modified by the trees. The analysis of societies in a more comprehensive and detailed manner and their classification on a dynamic and natural basis are problems of growing importance, and constitute one of the major objectives of the present extended field work.

RESEARCH IN FOREST INFLUENCES, BY E. I. KOTOK, C. J. KRAEBEL, W. C. LOWDERMILK AND F. E. CLEMENTS

The application of ecological concepts and methods to the study of forest influences in southern California has now been under way for three years. The investigation has been focused upon the relation of the climax chaparral and its burn succession to runoff and erosion, but this has demanded the concomitant study of a number of associated problems. Chief among these are the structure of the vegetation and its mapping in great detail on a large scale, the measurement of runoff and eroded materials by means of weirs and settling reservoirs, the physics of water and soil in contact, and the relation of underground organisms and parts to absorption and storage.

The crux of the problem lies in the reactions of the vegetation upon its habitat and upon the soil in particular. In this connection, Lowdermilk has brought decisive support to the conclusion that the soil mantle is the paramount factor in the absorption of rainfall and that its efficiency depends upon the vegetative cover, a forest or other closed cover maintaining the soil at its maximum capacity for percolation and storage. Where vegetation is in a climax stage, the surface removal is reduced to negligible amounts of soil. However, when the vegetation is destroyed, erosion of an accelerated order enters as a result of an increase in surficial runoff and upsets the balance represented by the geologic or climax norm of erosion.

The physical processes operative in the reaction of the community upon the soil have been worked out under controlled conditions in the laboratory and in experimental tanks, with the following conclusions:

(1) The ability of forest litter to absorb water to as much as 5 times its weight is insignificant in comparison with its function of maintaining the natural characteristics of a soil profile.

(2) The denuding a soil of its protective cover of vegetation sets in motion processes, which under moderate or high intensities of rain tend to seal the surface. Muddy suspensions of surficial flow are filtered at the surface to form a thin layer of fine material which fixes the rate of percolation for the entire soil profile.

(3) The ground litter of a forest or similar community prevents this sealing action by keeping the rain-water clear and thus preserving the natural porosity of the soil profile.

GRAZING RESEARCH, BY F. E. CLEMENTS, W. P. TAYLOR, M. J. CULLEY, C. K. COOPERRIDER, W. G. MCGINNIES AND C. T. VORHIES

The grazing exclosures established on the Santa Rita Range Reserve in southern Arizona and on the open range in northern Arizona at Seligman and Williams have now been under observation for 12 years. On the regulated Reserve, the initial response to protection against cattle, as against cattle and rodents combined, was very striking, but the actual gain in density of cover and especially of the most desirable species has been slower than anticipated. On the seriously overgrazed ranges at Seligman and Williams, the recovery has been much slower, the former showing little improvement for the first ten years. On both, the mid-grasses, *Kœleria*, *Elymus*, etc., were apparently absent; in the Seligman exclosure about half the area was occupied by a very open cover of *Bouteloua gracilis* and *eriopoda* and the other half by annual weeds. At Williams, *B. gracilis* formed a similar cover, in which the undershrubs, *Gutierrezia* and *Chrysothamnus*, were nearly dominant.

During the past six years the course of development in the latter under total protection has become more and more evident. The mid-grasses began to reappear and then to grow more abundant, *Kœleria* and *Elymus* first, followed by *Poa* and *Stipa*. Their competition was soon felt by the undershrubs, the smaller *Gutierrezia* disappearing first, while the taller deeper-rooted *Chrysothamnus* has been vanquished much more slowly. Today many of the bushes of the latter are dead and practically all the others are moribund. In the cattle-proof portion, accessible to rodents only, mid-grasses are still absent and *Chrysothamnus* is nearly as abundant and thrifty as outside. The rôle of rodents in the continued absence of mid-grasses has been demonstrated by installing a small rodent-proof area within this unit, in consequence of which the mid-grasses are reappearing. With the exception of two tufts of *Elymus*, no mid-grasses have appeared under total protection in the Seligman exclosure, though they occur on a neighboring rocky ridge. This is doubtless a result of more severe overgrazing, as well as of a lower rainfall than at Williams. The failure of the short-grasses to invade the associes of annual weeds has been a recurring puzzle, but it now seems certain that this is due to annual surface flooding, which renews the denuded area.

A preliminary outline for grazing research has been completed and distributed to investigators in this field during the year, and it is hoped that this will serve as the basis for a comprehensive treatment of the subject later. In addition, the first progress report on the exclosures and related problems is being prepared for eventual publication.

BIO-ECOLOGY, BY F. E. CLEMENTS AND V. E. SHELFORD

The concept of the community as a complex organism necessarily involved the idea of a single unit composed of plants and animals, but progress in this direction was delayed by the traditionally specialized training in the two fields, botany and zoology. While the first proposals to this effect came from plant ecologists,[1] these were naturally of little avail until zoo-ecologists had reached this conclusion more or less independently.[2] Looking backward from the present vantage-ground, such a rapprochement now seems to have been inevitable, a conclusion reinforced by the independent development of behaviorism and of emergent evolution, primarily phases of zoo-ecology but chiefly concerned with human relations. Behaviorism closely resembles the autecology of plants in that it employs measurement, experiment and development to some degree, though chiefly now in the study of the human species. Emergent evolution is a late recrudescence of an earlier philosophical aphorism that the whole is more than the mere sum of its parts,[3] and to this extent is in complete accord with the concept of the community as a complex organism with a development, functions and structures of its own.[4]

The inclusion of the animals in the community extends but does not alter the fundamental concepts of development and structure, of succession and climax. Climaxes are found to exist in the sea as on land, but the ocean dominants are animals and not plants, except for a few litoral communities of seaweeds perhaps. The ground-work of land communities is constituted by plants, within which animals find their proper rôle, usually subordinate in the basic processes of dominance and reaction, but coordinate or even controlling in that of coaction. When man or domesticated animals enter the situation, coaction may proceed so far as to pass into striking reactions, as is true likewise of burrowing animals from rodents to earthworms. Such outstanding coactions as the fire subclimaxes in forest and grazing ones in grassland exemplify the profound effects of animals in community life whenever number relations become abnormal.

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[1] *Research methods in ecology*, 1905; A. G. Vestal, *Internal relations of terrestrial associations*, Amer. Nat., vol. 48, 413–445, 1914.

[2] V. E. Shelford and E. D. Towler, *Animal communities of the San Juan Channel and Adjacent Areas*, Publ. Puget Sound Biol. Sta., vol. 5, 33–73, 1925.

[3] C. L. Morgan, *Emergent evolution*, 1926. W. M. Wheeler, *Emergent evolution and the development of societies*, 1928.

[4] *Development and structure of vegetation*, 1904. *Research methods in ecology*, 1905. *Plant succession*, 1916. *Development and structure of the biome*, 1916.

It is evident that the dynamic units already established by the plant ecologist in the analysis of vegetation apply equally well to the biotic complex or biome, the animals again assuming their proper place in these alongside of the plants. This is usually more obvious in the case of the much more extensive and permanent climax units, *viz*, eoclimax, panclimax, formation, association, consociation, faciation, lociation, society, etc., but it holds likewise for the seral ones, associes, consocies, socies, colony and family. However, since animals are typically mobile, it is essential to recognize animal groupings within the biotic units based largely upon the dominant plants, and this has been done on the basis of number or predominance, as in the case of presociety and presocies. New units and terms are also necessary to the understanding of minute short successions of subsessile animals, especially larvæ, and fungi in decaying matrices, such as logs.

The cooperative development of bio-ecology on the dynamic basis has been carried on for the past ten years in several regions, both on land and in water,[1] and has been reflected in part by several treatises.[2] It is now expected that a comprehensive outline will be available in published form in the course of the year.

PALEO-ECOLOGY, BY F. E. CLEMENTS AND R. W. CHANEY

The further application of the principles of paleo-ecology as laid down in *Plant Succession* (1916), to earlier fossil floras than those of the Miocene and Oligocene demonstrates that they are generally valid, though requiring more elaboration in connection with climatic mass migration and the phylogeny of climaxes and genera.[3] The analysis of the Miocene Mascall and the Oligocene Bridge Creek Floras on the basis of modern relict ones in the same general region yielded striking justification of this procedure, but the Eocene Goshen flora of western Oregon has no such present-day counterpart and it became necessary to broaden the method to take in much wider migrations. The consequence was the discovery of a related modern flora in Mexico and Central America, warranting the assumption of climax and climatic continuity between these widely separated regions in the Eocene, followed by widespread withdrawal in the face of desiccation and cooling. It appears probable that this took place chiefly along the coast, however, and that conditions may have been different in the interior.

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[1] F. E. Clements, ***Biotic Succession; Bio-ecology,*** Carnegie Inst. Year Books Nos. 19–22. 1921–23; F. E. Clements and V. E. Shelford, ***Id. Ib.*** vol. 26, 1927; V. E. Shelford, ***Ib.*** 25–26, 1926–27.

[2] A. O. Weese, ***Animal Ecology of an Elm-maple Forest,*** Ill. Biol. Mon. 9, 345–438; 1924. I. H. Blake, ***A Comparison of the Animal Communities of Coniferous and Deciduous Forests. Ib.,*** vol. 10, 371–520, 1916. V. G. Smith, ***Animal communities of the deciduous Forest Succession,*** Ecology, 9, 479–500, 1928. M. W. Shackleford, ***Animal Communities of an Illinois Prairie. Ib.,*** vol. 10, 126–254, 1929. R. D. Bird, ***Biotic Communities of the Aspen Parkland of Central Canada. Ib.,*** vol. 11, 356–442, 1930.

[3] F. E. Clements. The phylogeny of climaxes. Carnegie Inst. Year Book No. 28, 202, 1929.

In consequence, it has become more important than ever to subject the rich Cretaceous flora of the Dakota and related periods to a critical scrutiny, refine the generic determinations, and harmonize the vegetation with the ecological principles already applied to the Tertiary floras. For this, it will be necessary to make more extensive use of the newer methods in phylogeny and to reckon fully with the probability that mass migration and evolution of an eoclimax may have rendered the polygenesis of genera a more or less regular process. At the very least, this is a plausible alternative to the several conflicting hypotheses advanced to explain the presence of many families and genera more or less throughout the tropics. Moreover, it seems certain that the Angiosperms of earliest appearance in the Cretaceous are not primitive, but were already highly specialized and were in all probability preceded by a long line of ancestors reaching back to Permian uplands.

This problem can also be approached more directly from the present by combining ecologic and phylogenetic methods in proceeding from the climax and panclimax backward to the community ancestor, the eoclimax. This is being attempted at present for those panclimaxes, *viz*, the arct-alpine, and the three boreal ones, coniferous and deciduous forest and the prairie-steppe grassland, in which our knowledge suffices for a preliminary endeavor at least. For the tropical and austral panclimaxes, this possibility is more remote, though so great is the significance of the first that it is desirable to collate the available material and outline the problems at an early date.

A concise but fairly comprehensive outline of the principles and methods of paleo-ecology has been under way for some time, and will appear in the near future.

RESEARCHES IN PALEOBOTANY

By Ralph W. Chaney

A continuation of the study of the Goshen flora of Oregon which has been in progress for several years with the cooperation of Dr. Ethel I. Sanborn, of the University of Oregon, has emphasized its similarity to the living forests of Central America. A brief field survey of the modern vegetation of the Canal Zone, especially at the Barro Colorado Island Biological Laboratory, together with a study of herbarium material, has resulted in the conclusion that during the late Eocene there was a northward extension of sub-tropical conditions on the Pacific Coast comparable to that in the southeastern United States during the same period. The fact that many of the members of this Eocene sub-tropical forest have closely related modern equivalents in existing paleotropical as well as the neotropical forests suggests that the ancestral stock of the forests in both hemispheres may have had a common source, perhaps during the Cretaceous. In general the Goshen assemblage is more similar to the forest now living on the Pacific slope of Central America than to the Atlantic slope and Antillean forests.

It differs in many respects from other Eocene floras both of western and eastern America.

Dr. Sanborn is preparing for publication a discussion of the Comstock flora which is found a few miles south of Goshen and in beds somewhat older. This flora has much in common with the Clarno flora of the John Day Basin of Oregon, and with recently discovered floras on Cowap Creek near Mount Baker, Washington, on Montgomery Creek east of Redding, California, and in Plumas County, California. The material from the new Clarno locality is of particular value since it establishes the Eocene age of this flora and its relation to numerous other floras in Washington, Oregon and California. The collections from Plumas County, California, corroborate the idea which has been held by the writer for some years that certain of the floras from Auriferous Gravels, including probably those from Chalk Bluffs which are the best known, are considerably older than Miocene. That there are floras of Miocene age in the Auriferous Gravels is conclusively shown by a recent collection in Nevada County which is made up entirely of species characteristic of the Miocene Mascall formation of the John Day Basin. It is therefore apparent that floras of at least two ages are represented in the Auriferous Gravels. A further collection and study of the fossil floras on the western slopes of the Sierra Nevada may be expected to throw much light not only on the distribution and character of the Tertiary floras of California, which are at present imperfectly understood, but on the history of the orogeny of the Sierra Nevada.

Preliminary collections have been made in the Sooke formation of Vancouver Island, British Columbia, which indicate the Oligocene age of these deposits. Collections from several other new localities in the Tertiary of Washington and Oregon will extend the limits of well-known Tertiary floras of western America and add important elements to these fossil assemblages.

The studies of Charles B. Read on the Tertiary wood of Yellowstone National Park have progressed to the point of completion of the first of a series of papers on the fossil wood of this region. In view of the abundance of wood in the Tertiary record, continued study of this material will furnish evidence of critical importance to the problems of Tertiary paleobotany. Additional collections of leaves associated with the wood at Yellowstone, which have been made by Messrs. Mason and Read of the University of California, suggest that at least part of the floras of this region referred to the Miocene may be somewhat older.

A comprehensive paper on the Pliocene floras of California by Dr. Erling Dorf of Princeton University has been completed. Collections have been made at seventeen localities, most of which have been recently discovered, and thirty-four species have been determined. The plant assemblage has a less mesophytic aspect than that of the Miocene and earlier Tertiary floras of western America, and appears to represent the vegetation of a region in which topographic barriers comparable to those of today were present to modify the earlier forests and make them less homogeneous.

Extensive collections have been made by Mr. Herbert L. Mason from the Pleistocene formations of Tomales Bay, California. The twenty-five species are represented for the most part by fruiting structures and wood, and make up an assemblage similar to that of other Pleistocene floras of coastal habitat in the state.

RESEARCHES IN PALEOBOTANY

By G. R. Wieland

In the Year Book for 1929 (p. 205) there is given in simple form the general problem of flowering gymnosperm investigation, in what is believed to be its bearing on the origin of the so-called higher types of flowering plants. The object was in reality to outline the field for future research, as well as to recite what is done, so far as possible within the scope of two printed pages.

The Mesaverde Cycadeoids

The second season of field exploration in the San Juan basin of New Mexico has resulted in nearly doubling the petrified cycad collections from the Mesaverde Cretaceous in bulk, and much more than doubling the value of the collection as it now stands. As already told, the specimens are isolated, and their assemblage, depending almost entirely on what has been seen and remembered by the Navajos, is not like any other field task. Moreover, the specimens are usually incomplete. As eroded out, the trunks, many of which are crushed and flattened, usually break up into segments readily scattered and lost.

Yet, as the collection now includes scores of such specimens with variety of feature, many individuals are fairly if not completely represented. Further field work aiming to keep these collections in a representative scientific entirety is obviously and urgently advisable. The best "find" of the past season is that of a flattened but complete globular trunk bearing tiny seed cones, and at least one adventitious frond of the characteristic pinnate type, all going to indicate a new species distinct from the more columnar types. Another is a remarkable segment from the upper portion of a columnar stem showing the plant in fruit all over a broad zone just below the summit, and with an old peduncle zone just beneath. Other very striking trunk segments show considerable areas with the young peduncles in all frond axes, with seed cones in many instances present and complete. These young cones are no larger than those of a cowslip flower, and the relation of staminate fruiting to them is still unsolved.

Despite weeks of laboratory search with a lens and later the sawing through of many axes in series which will afford striking illustration, the lively expectation that the stamens would be found thus remains unsatisfied. However, because 11 or 12 pairs of bundles have been seen about the cone base indicating the staminate supply, it is believed the flowers were perfect and the stamens whorled—not spirally set as in magnolias. In any case, whether fused into a disk, single and basal, or spiral-set, the stamens were small, doubtless without pinnæ, and with few synangia.

Seen in bulk the Mesaverde cycadeoid collection is a most imposing one. There is not in all those tons of specimens, unless in the case of adventitious fronds, or the few trunk summits recovered, a single frond base without its complementary axillary peduncle, old or young, or actually bearing cones as the case may be. Primarily the series seemed to indicate monocarpy; especially so in the light of the earlier species *Cycadeoidea dartoni* of the

Black Hills Como, with its marvelous series of mature seed cones, and the *Cycadeoidea masseiana* of the Scaly Clays of Italy, with younger axes. But the specimen mentioned above with a zoned production of fruits is not monocarpic; although such a free growth of axial fruits about the summit of the trunk could not go on year after year, unless the frond growth occurred with a rapidity not elsewhere seen in cycadeous plants. Hence, that zoned fruiting shows in these cycads exactly the habit which could readily change toward or away from monocarpy, it being certain that one or the other change did occur, and is now fully illustrated in the cycadeoids, taking them as a greater group of petrified species and genera. Which was the more ancient form, the monocarpic, the more or less annual type marking perhaps the majority of Mesaverde cycads, or the sparse giant flowered and branched trunks of the Cycad National Monument?

While not yet possible of direct proof, there must be the very strongest suspicion that the old type was small flowered and bore those flowers in the axils of all leaf bases; that in one word the Mesaverde cycads, while occurring so much later in geologic time than the sparse flowered forms, are botanically nearer the primitive type. In that case it is easy to picture related forms more and more freely branched, which also bore their flowers, fruits, or seeds in the axils of all leaves—types which began a reduction of their foliage, or else always had more or less needle-like foliage, and which at last segregated fruit production to an axis of limited growth. So arose the conifers in which the frond is at last reduced to a bract, the fertile axillary shoot or even flower to a seed scale.

Though told briefly, it will be seen that such views give unity and simplicity to cone and flower. Both arose very early and have the same initial history. The primitive flowers and cones would be small. Large flowers and cones would be secondary, and largely explicable as due to or following foliar and stem change. The large flowers of *Magnolia grandifolia* would have got their size in Cretaceous times; the cones of the Coulter's pine likewise. Such views leave the living cycads as a blind line never related to any of the seed types that persisted, except in pre-floral times.

There is an apposed view somewhat easier to picture. In the foreground is the carpellary leaf of more or less cycadeous form. The seed ferns play the great rôle. Their apical fronds produce seeds only; the more basal fronds microspores. Next, the carpels so arising undergo reduction and then are borne on axes of limited growth. Simple cones of both sexes thus arise; also amphisporangiate cones which later become flowers. There is much giantism, then long courses of branching and reduction. Cone and flower would be much further apart than in the first conceived course of change.

Maybe, both of the above conceived courses of change occurred, with the first leading into the angiosperms and making them and not the conifers the oldest of seed plants. Obviously what is wanted is the discovery of key fossils. It is contended that taking evidence in its more visible aspects there is nothing biologically improbable about either of these views, nothing contradictory geologically or in the occurrence of fossils. The question merely is whether change was in the main direct after the seed stage was primitively reached, or indirect with long courses of reduction as more and more branched types arose.

THE CERRO CUADRADO CONIFERS

Just as the anthesis of the cycadeoids aids in reaching out beyond anatomical facts alone and almost forces into view hitherto unseen vistas of floral change, so the sectioning of the Cerro Cuadrado petrified cones helps to clarify ideas of cone origin. Never before has a series of petrified cones of conifers been so freely cut that description even takes the form of simple tabulation. The evidence is convincing that the conifers are an extremely specialized homogeneous group as they remain on earth today. As foliar specialization went on, the old open, lax cone, or more exactly speaking leafy inflorescence, made up of a series of seed-bearing shoots axillary to a bract series, was compacted, bracts and all, into the "seed cone," often exemplifying giantism.

Now, flowers and cones are alike axes of limited growth, usually subtended by one or more protecting modified leaves, scales, bracts, sepals or petals. The function of the subtending bract depends in the conifers on whether the order is primary as in staminate cones, or secondary as in "seed cones." The latter are in fact not cones at all, but elementally inflorescences. They correspond either to the inflorescent groups of staminate cones, or else alike to the short shoot leafy axis of pines. Nevertheless the identity of the bract runs through, and it doubtless goes all the way back to primitively fertile organs, maybe even those of lycopods. Why botanists have been slow to reach this broader definition of the bract, utterly simple as it is, is not so clear. We have always been told that in the flower, after foliage leaves give way to bracts, the transmutation goes on to sepal, petal, stamen, and at last the carpel itself.

No less in conifers, the stamens must be of the same general nature as the bracts which merely become sterile, initially protective organs. Nor should the essential identity of stamen and carpel be lost sight of merely because of the order of branching in cones. There is no difference finally between the lax inflorescence of *Podocarpus andinus*, and the giant cone of Coulter's pine or even that of *Sciadopitys*. The unit or carpellary shoot must be the same as in *Acmopyle* or *Torreya*. What then was the original complexity or condition of the bract and carpel, or carpellary shoot in the conifers? Certainly the leafy or foliar shoots to which they are held analogous were in Cretaceous times often made up of many leaves; and certainly the carpels were not only in certain forms more carpel-like, but grouped—the inflorescent structure being lax, the types often small. Evidence fails as to whether the unit axis ever was amphisporangiate, either in its present second, or its primitive order of branching.

But without even mentioning Gnetaleans there was in any case such a more or less gymnospermous amphisporangiate axis somewhere playing a great evolutionary rôle in Carboniferous or Permian times. Nature had two open ways to develop the reproductive axis of limited growth suited to seed retention, one leading into flowers, the other into cones—and let the fact not fail of emphasis that ever since, foliage leaves, scale leaves, bracts, sepals and petals are all alike in all seed plants, merely sterile equivalents of stamen and carpel; at least so, if the problem of seed origin can be somewhat set aside as distinct. A "flower" of some kind must be as old as any cones, using the term for seed plants, and not with reference to amphisporangiate cones like those of Selaginella. The "cones" and inflorescences of conifers are in actuality the *superflowers*.

If then the orders are considered, it is seen that, whether in cone or flower, stamens have always been stamens, but that on the contrary while the carpel of the flower is of the same order as the stamen, that of the pine cone is of the next higher order. It is the flower that is simple and primitive and not the cone of the conifers. The latter, so far as related to angiosperms in any modern sense at all, would only be the excessively specialized descendents of utterly ancient and primitive angiosperms, instead of the reverse. Because then of the single order in microsporophylls and the two distinct orders in carpels of flowers or cycadeous cones on the one side, and the secondary or shoot-carpel of conifer cones on the other, those older ideas of Amentifers having some closer relation to conifers than to other angiosperms all fail. Because of their floral structure, the angiosperms are older than the conifers. The two lines have been separate nearly back to the origin of seeds.

Mesaverde Petrified Hardwood Forests

Considerable doubt has arisen about the age of the cycads of the Mesaverde. They occur about two-thirds up in what I have understood to be the great development of the formation about the Chuska Mountain. That would be above the most of the mined coal. Also the Mesaverde easterly from Oraibi and about Keams' Cañon in Arizona, as the result of long erosion, now seems to belong to the lower half only. But taking the general field relations, there was some question if the Mesaverde might not be older than the Pierre and a very distinct need to tie up the geologic mapping of Gregory further west in Arizona with that of Reeside in the San Juan basin in New Mexico. It is exactly along the unmapped Chuska front between the areas included in these surveys that paleontologic interest centers. In fact it has been more recently suggested by Reeside that the Mesaverde is the equivalent of the Niobrara Cretaceous. If so the single fragmentary cycadeoid from the Niobrara noted in these reports several years ago would fit the record. It was called monocarpic, and the features are in close agreement with the Mesaverde series.

Whatever the age of the San Juan Basin Cycads, in most striking association with them, petrified hardwoods of several species should now be recorded. The stems have been thin-sectioned and their determination is now under way. These represent trees up to several feet in thickness, freely associated with the cycads and conifers of species not determined. The hardwood structure is well preserved and the types likely fall within some of the well-known leaf species. Attention was called to a very symmetrical stem or stump about a foot and a half in diameter and weighing 900 pounds. This came from the cycad localities of the Chuska Mountain front 25 miles north of Gallup, New Mexico, and has been placed on view at the railway station at Gallup. Another fine trunk segment of a different species was shipped back to Yale. The material is scattered but abundant.

This in all probability marks the finest pre-Tertiary petrified hardwood forest yet found in North America, and excites the liveliest hope that the older petrified hardwoods may prove to be much more frequent than has long been supposed. Older types have been described from the English Greensand, but only in very fragmentary form. Here there is an occurrence as striking as that of petrified conifer forests. Moreover, of even more importance is the suggestion as to where such hardwood petrifaction may be awaited.

The English Greensand, it will be recalled, is more or less fluvio-marine, and the Mesaverde, as a heavy formation laid down near the western shores of the Niobrara or the Pierre Sea as the case may be, suggests the possibility of similar chemical conditions. For it is nearly certain that conifers are far more liable to petrifaction than dicots, the latter requiring some very quick, sure supply of monosilicic acid to reach petrifaction at all, and usually being found much broken down in lignitic beds where the conifers are still structurally intact. Seemingly, the lignitic stage is the one at which petrifaction must begin. Further confirmation of these ideas is had from the nature of the Tertiary occurrences of silicified dicots, either near the sea or in close association with eruptives as in the case of the dicots of the Lamar River Oligocene in the Yellowstone, frequent occurrences in the Cascades, and the first petrified woods found only this year in the Hawaiian Islands.

A further and very isolated instance of Oligocene dicot petrifaction I have just now observed is as remarkable. This occurs in the case of woods I collected as far back as 1898 along the Cheyenne at the base of the Oligocene White River beds. These stems at first laid aside as conifers, and not sectioned until very recently, prove to include well-preserved dicots, the first ever reported from their horizon. Those familiar with the White River beds know there are some very unusual conditions there, the beds at some time in their history having been extensively desiccated with deep cracking sometimes in quite vertical directions, and often cross-cut, with subsequent filling in of those cracks by great thin sheets of clear silica. Was desiccation due to some access of internal heat, followed by an upwelling, from deep sources, of thermal alkaline solutions carrying the active monosilicic acid that brought about dicot petrifaction?

CLIMATOLOGICAL RESEARCH

By A. E. Douglass

In the past year, the studies of climatic cycles by the aid of tree rings has developed along several lines. The extended tabular matter necessary in producing the best mean sequoia record of growth for three thousand years has steadily progressed, and the results for the southerly Springville Grove are practically finished. A collection of specimens of the growth of modern trees has been made this year in Sweden and we now have a good distribution of six groups between Eberswalde in North Germany and Abisko in North Sweden. The cyclograph method of analyzing long records for periodic variations has been developed by using a motion picture camera controlled by an automatic exposure device; thus results may be projected on a screen in the form of a progressive analysis of the curve of observations or measurements, or individual cyclograms may be selected and held on the screen for special study. An alternative form of cycloscope depending on a variable grating has been constructed and used to present more clearly this form of cycle analysis.

And lastly, in connection with the paleo-botanical work of Dr. R. W. Chaney, the ring growth of the petrified trees in the Yellowstone National Park is being studied. A small group of specimens secured by Mason and Read in 1929 showed such promising variations of growth that larger numbers are now being secured. The plan of using a diamond drill driven by a gasolene engine is under test.

CYTOLOGICAL INVESTIGATIONS

By John Belling

During the year the work on chromomeres has been mainly with species of *Lilium* and *Fritillaria*. These plants give the largest and clearest chromomeres of any species yet investigated. The previous observations have been confirmed and a number of new points have been investigated. The main facts are as follows.

1. At leptotene each thread consists of a chain of minute closely-set chromomeres which are of different sizes. No trace of a longitudinal split is visible. Previous figures of the leptotene of the lily showing a continuous thread without chromomeres, or showing chromomeres of equal sizes, are due to too slow fixation.

2. At zygotene the two threads conjugate by homologous chromomeres coming together. As the two homologous threads are conjugating, it has been observed that one is almost a replica of the other with regard to the sequence of sizes of the chromomeres, as far as they can be separately traced. Since sometimes the conjugation is temporarily interrupted, forming a loop, but occurs again further on between homologous chromomeres, we must it seems infer that homologous chromomeres attract one another at this stage, but do not attract non-homologous chromomeres. This postulates over two thousand different attractions.

3. In pachytene it may be seen that all the chromomeres have conjugated with their fellows of the same sizes. In a small percentage of cases, however, a chromomere on one side finds no mate on the other side. Sometimes two chromomeres on one side are connected with one on the other side. Cases have been seen where three chromomeres on one side are apparently connected with two on the other. Further examination of cases supposed to be the conjugation of chromomeres of different sizes has shown that some at least are due to the longitudinal approximation of non-homologous chromomeres. Special destaining at early pachytene has shown that there are then two, not four, rows of chromomere cores, or genes.

4. At diplotene, homologous chromomeres of the same sizes on each side have been observed in similar series, just after separating. They are apparently separated at the primary split only, the secondary split being then usually unfinished.

5. Since crossing-over is a *vera causa,* and on any hypothesis seems to lead to chiasmas, a hypothesis for the presence of chiasmas is out-of-date unless it takes into account the fact of crossing-over. Further counts of chiasmas by the writer seem to confirm this view of their origin.

DEPARTMENT OF TERRESTRIAL MAGNETISM[1]

LOUIS A. BAUER, DIRECTOR EMERITUS
JOHN A. FLEMING, ACTING DIRECTOR

GENERAL SUMMARY

The year covered by this report (July 1, 1929, to June 30, 1930) has been a momentous one in the history of the Department because of the disaster to the *Carnegie* at Apia, November 29, 1929, in which Captain James Percy Ault, chief of the section of ocean work and commander and scientific leader of the *Carnegie,* lost his life. The scientific work of Captain Ault finds its chief expression in the achievements of the *Carnegie,* of which he had been the commander during the last fifteen years of her activity. To him is due in large part the continued success of the later cruises, and the unique series of observational records obtained during Cruise VII will henceforth serve as a basis for practical and theoretical studies in geophysics over the oceans. The general esteem in which he was held and the great loss not only to our own sciences of terrestrial magnetism and electricity but also to oceanography occasioned by his death is evidenced by the resolutions of condolence adopted by scientific organizations everywhere and by innumerable letters from investigators and national organizations interested in geophysics both in America and abroad. It is not too much to say that the work achieved on this unfinished cruise will take rank as a great contribution to oceanography, much of it in the Pacific being of distinctly pioneer character. The data obtained have added conspicuously to knowledge and serve to emphasize how great is the loss occasioned by the disaster to the vessel in the non-realization of the plans for the remainder of the cruise and in the loss of Captain Ault's services in reducing and discussing the data.

Dr. Louis A. Bauer, Director of the Department since its establishment April 1, 1904, for whose energy and breadth of vision the Department will always be indebted in large measure for the development of its program, retired from this position because of ill health January 1, 1930, with the title of Director Emeritus. Arrangements were made that he continue as Research Associate of the Institution to undertake such special investigations as he may select and as may be permitted by the condition of his health. John A. Fleming, associated with Dr. Bauer as Chief Assistant from 1904, as Assistant Director for observational and administrative work during 1922 and 1923, and as Assistant Director in charge of operations since 1924, was made Acting Director of the Department January 1, 1930.

The progress of the Department's research activities in the report-year has been good despite these great losses in its material and personnel resources and despite the urgent and unusual demands caused by the loss of the *Carnegie* and the immediate undertaking of the preparation for publication of the observational results obtained.

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[1] Address: 5241 Broad Branch Road, N. W., Washington, D. C. (instead of Thirty-sixth Street and Broad Branch Road, as heretofore; the location of the Department is the same, the street designation only having been changed).

A more complete program of atmospheric-electric observations than ever before attempted was successfully carried out at sea. The conductivity of the atmosphere was for the first time continuously recorded on a vessel, beginning September 3, 1929, with apparatus constructed in the instrument-shop of the Department and installed on the *Carnegie* during her call at San Francisco. The continuous registration at sea of air-potentials and air-conductivity brought out more vividly than the eye-readings obtained heretofore the advantages of atmospheric-electric observations at sea, especially for studies of world-wide and cosmic effects. Among these may be noted the confirmation of the universal-time phenomenon in the diurnal variation of the electric potential of the atmosphere.

Special efforts were made to intercompare instruments used in measuring penetrating-radiation at sea to determine the reliability of the instruments and whether variations heretofore observed have been due to actual changes in the intensity of the radiation or to some instrumental or local causes.

A modified method was developed having important new possibilities in the study of the nature and properties of the penetrating-radiation, depending on the new Geiger-Müller electron tube-counter as used by Bothe and Kolhörster.

The experimental work on the earth-inductor method of measuring the magnetic horizontal-intensity of the Earth's field was most encouraging. It indicates the feasibility of this method for measurements at sea and is therefore being continued—a continuation particularly desirable in view of the probability that some magnetic measurements will be made on surface-ships and dirigibles in the future.

The high-potential work, begun several years ago with the aim of providing a means for investigating the innermost structure of matter—the atomic nucleus—and other fundamental problems of electricity, magnetism, and radiation, has made very encouraging progress. Two difficulties encountered in the reliable operation of vacuum-tubes at very high voltages, namely, the shattering and puncturing of the glass and the destructive effects of the very fast and powerful electrical surges which occur when such a tube occasionally flashes, have been successfully overcome, and a practical design was attained for a high-voltage vacuum-tube to operate reliably at potentials up to two million volts produced on a laboratory scale by Tesla coils. Experiments indicate that the present design can be readily extended to twice this voltage and even more, without any fundamental changes. Measurements have been made on the output of very fast electrons from these tubes which show that they are equivalent to the beta-rays from radium, as was expected. Preliminary observations also indicate that these tubes produce very penetrating X-rays equivalent to the gamma-rays from radium so widely used in cancer therapy. It is expected that these tubes will make possible the production of artificial rays considerably exceeding the energy-equivalents of those available from radium, thus providing a fundamental tool for many new investigations.

Satisfactory progress has also been made in the extension by Breit of his theoretical investigations in atomic physics.

The photographic observations of reflections of radio waves from the Kennelly-Heaviside layer give increasing evidence of the fundamental importance to the phenomena of terrestrial magnetism of this method of investigating the upper atmosphere. Further possibilities in radio investigations have been supplied by the provision to install at the Watheroo Magnetic Observatory a radio station for the study of short-wave propagation, of plane of polarization of incoming short waves, and of interrelation of short waves with magnetic and atmospheric-electric elements. Here, too, a static recorder loaned for cooperative work by the Radio Research Board of the Council for Scientific and Industrial Research in Australia was continuously operated and auxiliary apparatus installed to eliminate the 180° ambiguity in direction of arrival of static.

The programs of magnetic, atmospheric-electric, earth-current, and meteorological investigations at the Watheroo and Huancayo observatories were practically uninterrupted throughout the year, as also the atmospheric-electric work in the deck-observatory at Washington. Satisfactory and profitable cooperative work in atmospheric electricity was continued with the Apia Observatory. The cooperation with the United States Coast and Geodetic Survey at its Tucson (Arizona) Observatory to record continuously air-potentials and both positive and negative air-conductivity was initiated; the results beginning the latter part of October indicate this site to be well suited for such work and one relatively free from those disturbing local features so often encountered over land.

Substantial progress was made in the investigations of magnetic storms and in particular of the storm of September 21, 1925, for which the discussion of records obtained at twenty-five widely distributed observatories seems to indicate that the changes in the Earth's field represented by the study of the individual details, principally those of the beginning of the storm, are dependent to some extent at least upon local regional conditions, although these conditions are not yet known.

While the contribution from the observations made aboard the *Carnegie* in the fields of terrestrial magnetism, atmospheric electricity and upper-air currents over the oceans in every way has justified the program in these fields, the reductions and compilations of the work in physical and chemical oceanography have revealed new and significant features in oceanic circulation not only in the Atlantic but particularly in the Pacific. This work, together with the collection of bottom-samples, the development of new features of bottom-configuration, the collection of a great number of biological samples for the study of the distribution of plankton, and other oceanographic work, is in the estimate of skilled American and European oceanographers a most significant contribution to oceanography and one upon which the foundation may be laid for future programs. All reductions of this work have been greatly forwarded by the courtesy of the Geophysical Institute of Bergen, Norway, in allowing H. U. Sverdrup of its staff to spend about six months in Washington and of the Scripps Institution of Oceanography in permitting G. F. McEwen and E. G. Moberg also about a month each in Washington for the purpose of reviewing the work done and initiating and forwarding its preparation for communication in scientific channels.

Developments of secular variation made possible through the results obtained by the *Carnegie* during Cruise VII and Fisk's investigations in this subject have resulted in significant developments indicating the important rôle which the accumulation and the investigation of such data may have in the study of the Earth's crust as well as in the study of theories of terrestrial magnetism.

The policy of cooperating with other investigators and organizations interested in terrestrial magnetism and electricity has been consistently maintained, and many helpful contacts established which it is believed have at least contributed to the marked increase in geophysical activities, including the increase of secular-variation material so greatly needed from all parts of the Earth in the solution of problems bearing on terrestrial magnetism.

INVESTIGATIONAL AND EXPERIMENTAL WORK

TERRESTRIAL MAGNETISM AND ELECTRICITY AND COSMICAL RELATIONS

Those lines of theoretical research indicated in previous reports have been continued and extended during the report-year.

Solar activity and the Earth's magnetic and electric fields—The application of stereographic projection by Peters to the analysis and investigation of magnetic disturbances and their relations to solar conditions was continued. Study was made by him and Wallis of the directions in space and of geographical distribution of the initial changes in the Earth's magnetic field as indicated by the magnetograms recorded at twenty-five observatories at the beginning of the magnetic storm of September 21, 1925. The interest in this research was indicated by the promptness with which cooperating observatories supplied reproductions of magnetograms and the necessary data for the compilations (see p. 311).

This study was supplemented by that of Wallis in an examination of the geographical distribution of magnetic disturbance through (1) discussion of results and comparison of photographic records obtained during the MacMillan Baffin Island Expedition at the Bowdoin Harbor Observatory 1921–22 with those at seven other well-distributed observatories for the storm of March 14, 1922, and (2) by a similar comparison for the storm of January 29, 1924, as recorded at the Refuge Harbor Observatory maintained in 1923–24 by the MacMillan North Greenland Expedition, with magnetograms at nine other well-distributed observatories. These discussions indicate that during magnetic storms the zone of maximum auroral frequency is the region of most intense magnetic activity and confirm a sharp drop in both auroral frequency and magnetic activity after passing this zone southward with a comparatively low level of magnetic activity in temperate and tropical latitudes except for a slight rise in the region of the magnetic equator (see p. 320).

Diurnal variation—Wallis made investigations of the diurnal variations at arctic stations in connection with his compilations for publication of the data obtained on the MacMillan Baffin Island and North Greenland expeditions, as affected by disturbances. In declination the usual effect appears to be to convert a double diurnal wave into a single wave but with greatly exaggerated amplitude, while in both horizontal intensity and vertical intensity the ordinary diurnal wave of the normal day is retained in form but much exaggerated in amplitude.

Edmonds and Johnston, with the help of Seaton and Miss Balsam, have prepared for publication the data and graphs of diurnal variations obtained at the Watheroo Magnetic Observatory and have made harmonic analyses of the resulting data for the five international quiet days and for all days in their means for each month and for each year of the series of observations at the Watheroo Observatory since 1919. Similar work has been completed by Wallis for the two arctic stations above mentioned.

Measures of magnetic activity—Further attention has been given the study of suitable methods and formula to give an effective measure of magnetic activity. Duvall began and reported preliminarily on a measure using an ordinate-integrator suggested by him, designed by Huff, and constructed in the instrument-shop as the result of discussions of a proposal by McComb and Heck of the Coast and Geodetic Survey suggesting that the length of recorded trace in a magnetogram might be a good measure of this rather indefinite quantity. These preliminary results, in connection with comparisons of magnetic activity measured by this and other methods previously suggested, using the records for the month of March 1927, from the Huancayo, Watheroo, and Cheltenham observatories, not only show excellent correlation-factors for the daily means at Huancayo and Watheroo, but also an unexpectedly close correlation when measuring hourly activities. An advantage of this method would appear to be the reproducibility by any one of a definite measure for any particular magnetogram since that variation inevitable in personal judgment does not enter the result. It is noteworthy that the values obtained are in good agreement with other more laborious mathematical measures of activity as well as with the more simple international character-numbers.

Wallis has also approached this subject through an investigation of the vector-changes during a storm as well as the changes in the energy of the magnetic field. He finds these two methods usually giving concurrent results, although not invariably so.

Harmonic analysis of the Earth's field—Duvall has given considerable time to the study of the harmonic analysis of the Earth's field anticipating repetition of Bauer's mathematical analyses for the epoch 1922, now that there is a considerably greater accumulation of data and the promise of more observational material in the polar regions offered by the increased activity of explorers and proposed expeditions both in the arctic and in the antarctic.

Fisk and Duvall have also continued reduction of accumulated magnetic observations to common epoch in anticipation of the further development of such analysis.

Secular variation—Fisk's investigations of secular variation leave no doubt as to the great importance of this subject in the theoretical solution of problems involving changes in the Earth's field (see p. 296). His investigations have revealed some most interesting and important conditions governing isoporic movements. As the data increase, the complexity of the phenomenon becomes more apparent, and in the same ratio the importance of its bearing upon the study of physical conditions and movements within the Earth, too deep for penetration by other methods, is emphasized. Fisk, with the aid of Seaton, has prepared isoporic world-charts, that is to say, charts showing lines of equal annual change, applying to the approximate epoch 1920–1925 in declination, inclination, horizontal intensity, vertical intensity, and total intensity. One interesting feature of the research has been the indication that the region of increasing horizontal component is confined to the Northern Hemisphere except for a small area in the Indian Ocean and a smaller one near the mouth of the Amazon, with a maximum yearly rate of increase scarcely more than 30 or 50 gammas, which is less than one-half that found at several of the negative centers of change. Thus in the aggregate the Earth's field as represented by horizontal intensity is diminishing.

The compilations of secular variations over the oceanic areas made possible by the recent cruise of the *Carnegie* were made preliminarily by Ault and Fisk (see p. 292), and Johnston and Fisk are now engaged in an intensive and final discussion of all the data obtained by the *Galilee* and the *Carnegie* since the inauguration of the oceanic survey in 1905.

Cooperation with Boss in the investigation of the Department of Meridian Astrometry referred to on page 211 of last year's annual report has been continued. Data have been supplied him from time to time for his investigation in the correlation of changes in the rate of rotation of the Earth with those—perhaps secular, diurnal and irregular—of terrestrial magnetism and electricity.

Fisk and Fleming devoted considerable time to studying methods to determine upon suitable world-distribution of secular-variation stations and to studying the cooperative agencies of various governments and organizations by which coordinated and suitable plans to realize a definite program for securing secular-variation data at suitable intervals may be made. Memoranda regarding these matters have been prepared to be submitted to the Stockholm Assembly of the International Geodetic and Geophysical Union in August 1930.

Ship-deviations caused by motion of ship—The experimental extension of this research and design of additional necessary apparatus have been given consideration by Peters and Huff along general lines indicated by the earlier work of Peters.

Magnetic charts—The indexing of magnetic data for polar regions was continued by Peters. The *Carnegie's* material for use in preparing the 1930 editions of the isomagnetic world-charts for declination, horizontal intensity, and inclination of the United States Hydrographic Office was supplied to that Office. Ennis prepared, on the basis of this work, isomagnetic world-charts for 1930 drawn to suitable scale for use in compilations of the Earth's magnetic constants and for use in textbooks.

RESEARCH ASSOCIATES AND COLLABORATORS

A. E. Kennelly, Greenleaf W. Pickard, and H. U. Sverdrup have continued as research associates throughout the report-year, and grateful acknowledgment is made of their constructive suggestions.

Besides conferring during several visits to Washington with the Department staff, Dr. Kennelly has done much to forward our participation in the development of the arrangements, now so near actual realization, for daily broadcasts of cosmical physical data as mentioned in the last annual report (p. 212). Fleming, Gish, and Tuve have assisted him and the special committee of four, under the chairmanship of Professor C. F. Marvin, having this matter in hand. Dr. Kennelly, as a representative of the Institution, will present an account of the cosmical-broadcast arrangements in the United States at the Stockholm Assembly in August 1930.

The accumulation of observational and experimental results by Pickard and his associates was continued. During the report-year ending June 30, 1930, recording of night reception in the broadcast-band has been continued at Cambridge and Pasadena, so that there is now available nearly four and a half years of Eastern field-record from WBBM at Chicago and three years of San Francisco station-record at Pasadena. Correction is being started for seasonal effects which may improve results of investigations of solar correlations. Continuous recording of low-frequency station WCI of Tuckerton, New Jersey, started in 1928 at Newton Centre, has been continued at Tufts College, Massachusetts. The investigation of transmission-phenomena at low frequencies is particularly important at the present time, as the number of regularly operating stations in this band is rapidly decreasing.

Acting upon a suggestion by Hulburt, a comparison of radio reception and terrestrial magnetism with meteor swarms has been started, as it seems possible that meteor showers may observably disturb the Kennelly-Heaviside layer. A preliminary examination of reception on the normal dates of the Lyrid, Perseid, and Leonid swarms for the past four years is rather encouraging.

Beginning in July 1930, the night recording of WBBM will be transferred from the Harvard Astronomical Laboratory at Cambridge to Tufts College. It is planned to make Tufts College a New England center for recording field-strengths in low-frequency, broadcast, and high-frequency bands, as well as in echo and other investigations of the Kennelly-Heaviside layer.

The research on the Kennelly-Heaviside layer has had the collaboration, as stated in the last annual report (pp. 213–214), of a number of investigators. Among these are A. H. Taylor of the Naval Research Laboratory, P. A. de Mars and G. W. Kenrick of Tufts College, and L. W. Austin of the Bureau of Standards. Pickard's apparatus, which had been in use at Harvard University, has now been placed at the disposal of H. T. Stetson, who will use it in his cooperative recording work at the Perkins Observatory, Delaware, Ohio.

From July to February, Sverdrup continued in his advisory capacity, especially in matters relating to the oceanographic program of the *Carnegie*. From March 5 he was in residence at Washington, arrangements having been made through the courtesy of the Geophysical Institute of Bergen for him to so continue until some time in August 1930, to take active full-time part in the reduction and preparation for publication of the large amount of oceanographic material collected by the *Carnegie's* staff during the vessel's last cruise so unfortunately interrupted and terminated by her loss in November. Details of his valuable and constructive work in this connection are given elsewhere in this report. While in Washington he took active part in the cooperative and various activities of the Institution and Department. On April 8 he lectured at the Administration Building on "Some phases of oceanography," on May 1 to 3 he took active part in the proceedings of the American Geophysical Union and American Meteorological Society by presenting three papers dealing with the work of the *Carnegie* and the plans for the proposed International Polar Year of 1932–33, and on June 30 he broadcast from Washington in the series of radio talks under the auspices of the American Association for the Advancement of Science. (Abstracts of his communications are given on pp. 314–316.)

There has been collaboration throughout the report-year with many organizations and individuals. Of these may be mentioned the American Telephone and Telegraph Company. Matters referring to the program relative to certain earth-current measurements on lines of the Company have been discussed and continuous graphic records out of New York and out of Cleveland have been made available through Messrs. R. B. Shanck and C. G. Southworth of the New York office and E. V. Donelson of the Cleveland office. In the high-voltage work it was possible to cooperate with Professor Richard Cox of the Department of Physics of the New York University through the loan of some high-voltage tubes developed for experiments on the polarization of electrons and through tests with a high-voltage constant-potential apparatus available at the University.

One of the interesting features during the year has been the active, alert attention given by amateur radio operators to the transmission of messages from the *Carnegie* and from the Watheroo Magnetic Observatory.

Further evidences of the general interest in the fields of the Department have been indicated by requests to members of staff to prepare accounts on terrestrial magnetism and atmospheric electricty for university textbooks, for example, from Professor C. A. Culver of Carleton College and Professor Fred A. Saunders of the Jefferson Physical Laboratory, and for revised editions of the Physical Tables of the Smithsonian Institution. Soule has been requested to prepare a section on the instruments and methods for physical observations at sea for the proposed manual on oceanography to be published under the auspices of the Division of Physical Sciences of the National Research Council.

MAGNETISM AND ATOMIC PHYSICS

The experimental and theoretical work in atomic physics was continued by Breit (who resigned effective September 30 to accept a call to the New York University), Tuve, Hafstad, Dahl, and Patton (who was available for expert glass-blowing on a part-time basis—a courtesy for which the Department is under obligation to the United States Naval Research Laboratory). Breit continued as a Research Associate of the Institution Beginning October 1. Since then he has given some attention to the high-potential investigations and also some helpful counsel and suggestions concerning experiments in which the high-potential equipment may be used and in the work so ably carried on under Tuve. He has continued the general field of his investigations in atomic physics undertaken at the Department. The following summaries briefly review the experimental and theoretical progress made.

EXPERIMENTAL[1]

High-voltage work—A practical design of high-voltage vacuum-tube which operates reliably at very high voltages has been developed, and the production by these tubes of very high-speed electrons equivalent to those shot out from radium (beta-rays) was demonstrated. A brief mention of the preliminary design was included in the last annual report (p. 214). During this report-year these tubes were operated many times to potentials of nearly two million volts (1900 to 1950 kilovolts) without any sign of trouble with the tube. This voltage-limit is set by the dimensions of the oil-tank in which the tubes are operated. Voltages of approximately 1900 kilovolts have been attained with one end of the tube grounded; with a larger tank the other half of the tube could be added and twice this voltage reached with no additional modifications.

The design of these tubes is based on the cascade-method of Coolidge. Very small bulbs are used, the tube being comprised of ten or more units in series, each section being externally shielded from ground, and the voltage being divided among the sections by a potentiometer or by taps on the high-voltage coil. Two outstanding difficulties, which it was essential to eliminate before the practical operation of these tubes at very high voltages could be achieved, were overcome. The first was the shattering and puncturing of the glass walls—the limitation on all of the earlier tubes. It was found that this was entirely eliminated if the (Pyrex) glass of the whole tube was "heat-worked" before assembly. The second difficulty arose from the destructive effects of the extremely high-speed electrical transients or surges which are set up when a gaseous discharge or flash takes place in a tube; this flashing occurs a few times with each new tube as the voltage is gradually raised in the "seasoning" process. A series of by-pass condensers between the tube-sections has eliminated trouble from this source.

Attention is now being concentrated on measurements of the output from these tubes. Measurements have been obtained of the magnetic spectrum of the high-speed electrons (artificial beta-rays) shot out from the grounded end of tubes operating at 1250 to 1500 kilovolts which show that the electrons from the filament at the high-voltage end attain the expected velocities in their travel down the tube. Preliminary observations have also been made of the very penetrating X-rays (artificial gamma-rays) which are produced when these electrons strike a target in the end of the tube. When it is realized that most of the beta- and gamma-rays emitted by radium have voltage-equivalents under 1500 kilovolts, and that these tubes can be operated at three or four million volts by simple addition of the complementary half, putting both ends of the tube at high voltage, the significance of this development can be appreciated. Although considerable changes will probably still have to be made, especially in the way of increased intensity by the use of a more continuous voltage-source than the Tesla coil, in order to adapt this new tool effectively to the studies in atomic and nuclear physics for which it was developed, it is felt that the fundamental difficulties encountered in evolving tubes to withstand very high voltages have been successfully overcome.

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[1] From the report of physicist M. A. Tuve.

The upper atmosphere (Kennelly-Heaviside layer measurements)—The importance to terrestrial magnetism of studies of the ionized region of the upper atmosphere by radio methods has become increasingly evident during the past two or three years. Radio observations point strongly to the conclusion that the conducting region in the upper atmosphere, which was assumed by Balfour Stewart nearly fifty years ago in order to account for variations of the compass-needle, is identical with the Kennelly-Heaviside layer which is responsible for so many phenomena of radio wave-propagation. It has been found that magnetic disturbances are accompanied by marked changes in the height and other characteristics of the radio reflecting-layer, but systematic observations on various frequencies (or wavelengths) over a period of several years will be necessary before these variations can be quantitatively known.

Observations of the Kennelly-Heaviside layer by the echo-method developed at the Department in 1925 have been continued during this year to the extent to which the Naval Research Laboratory found it possible to transmit the necessary schedules of special signals. The major characteristics of the echoes were similar to those previously observed (see previous annual reports). Extensive cooperation in these observations was effected with the Bureau of Standards and with Tufts College. Installation of new transmitters is now in progress, and upon their completion the Naval Research Laboratory has very kindly arranged for an extended series of transmission-schedules at various frequencies for a systematic study of the layer, especially in relation to the phenomena of terrestrial magnetism.

Penetrating-radiation—A modified method having important new possibilities was developed for using the Geiger-Müller "electron tube-counter" for studies of great penetrating-radiation ("cosmic rays"). About a year ago Bothe and Kolhörster showed that the coincidences between the counts of two such tube-counters placed close together in a vertical plane were due to the very fast electrons (beta-rays) which either constitute the penetrating-radiation or are the immediate result of the very hard X-rays (gamma-rays) which comprise the primary radiation. Analytical experiments on these rays by ordinary methods are nearly impossible, since any slit-system for defining a beam of the rays would have to be many feet thick because of their great penetrating-power. However, by recording the coincidences of three (or more) counters such experiments can be made. The first two counters serve as a slit-system picking out a beam of the rays, which is then deflected by a magnetic field or a scattering block or otherwise experimented upon, and the third counter, which is movable, detects the new position of the beam. Using a magnetic field to deflect the beam, this method provides a quantitative means for obtaining the complete energy-spectrum of the penetrating-radiation. Absorption-experiments at best yield very complicated evidence of such a spectrum, because of secondary effects. An automatic device using vacuum-tubes to record only the coincidences of the counters, eliminating the residual effects of the separate counters to any degree desired, was also developed for these experiments. Owing to the very low intensity of the penetrating-radiation received from small solid angles of the sky, which forms the beam of rays which is observed in this way, observations must extend over considerable periods of time before results are obtained. Regular records are being made of the amount of the penetrating-radiation received from a band, about 15° wide, in the sky to detect whether there exists a measurable difference in the intensities of the penetrating-radiation received from the Milky Way and from other portions of the sky. Previous experiments looking for such an effect have lead to negative results, but they have been made with instruments which are sensitive only to very wide areas of the sky. This new instrument is of fundamental importance, since it opens a new extreme region of the spectrum (10^8 to 10^9 electron-volts) to analytical experimental attack.

THEORETICAL[1]

Theoretical aspects in atomic physics were further studied by Breit as Research Associate and work was done on the following subjects.

(1) The spin-interactions of two electrons were investigated by comparing theoretical results with the fine-structure of He and of Li^+. This work is a direct continuation of the theory mentioned in the report for 1928–29. It appeared at the time that the theory requires a new type of magnetic interaction. As a result of this year's work, it has been ascertained that the experimental facts do not admit the new terms and that they are in good agreement with the ordinary picture of the electron as a magnet. As a by-product the mathematical problem of two electrons has been simplified by reducing it from six to three dimensions. Computations of the energies of He and Li^+ which have been made by this method for the 2^3P-state are in good agreement with experiment. The calculations on Li^+ were done in collaboration with Mr. Granath of New York University.

(2) The effect of a nuclear magnetic moment of the order of several proton-units has been calculated for X-ray terms. The expected splitting of the K-terms is such as to cause energy-differences of the order of 20 volts for the heaviest elements. An experimental detection of the effect would require a spectroscopic resolving-power of better than 4200 for the K_α lines. The effect for K-terms is essentially simpler than that for optical spectra, because to a very good approximation all of the effect is due to one electron.

(3) Using the data of Schüler and the recently obtained data of Granath (at New York University) the *hyperfine*-structure of Li^+ is in agreement with a nuclear spin of $K=3/2$. This contradicts the interpretation of Schüler and Brück ($K=1/2$) and agrees with the band spectrum-evidence of Jenkins ($K=3/2$). Computations of the magnetic moment of the Li_7 nucleus are in progress in collaboration with P. W. Doermann of the New York University. The present value is between 3 and 4 proton-units.

(4) A theoretical discussion in collaboration with E. O. Salant of New York University of the mutual influence of molecules in a liquid or dense gas shows that the frequency-shifts of the infra-red absorption-bands of HCl and HBr observed by Salant, Sandow, and West are greater than the effect of the Lorentz-Lorenz force and are due to forces similar in their nature to the forces responsible for chemical binding.

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[1] From the report of Research Associate G. Breit.

EXPERIMENTAL WORK IN TERRESTRIAL ELECTRICITY[1]

The personnel regularly engaged at the Department during the year in the experimental and analytical work in atmospheric electricity, earth-currents, earth-resistivity, and associated phenomena were Gish, Wait, Rooney, and Sherman.

Atmospheric electricity—The testing at Washington of recording conductivity-apparatus for use on the *Carnegie* was completed early in the report-year, and this apparatus was installed on the *Carnegie* at San Francisco in August by Gish. He accompanied the vessel to Honolulu in order to make further adjustments under sea-conditions and to carry out special experiments. During this time three apparatuses for the measurement of penetrating-radiation were compared daily. Two of these were instruments designed by Kolhörster and tested by him prior to their delivery, one having been on the *Carnegie* from Hamburg, barring an interval during which it was returned to Washington for repairs. The other Kolhörster-type instrument had been brought by Gish from Washington and had been compared with Millikan's cosmic-ray electroscopes at Pasadena. The third was the regular *Carnegie* apparatus which had been in use on all cruises since the beginning of Cruise IV. The object of this comparison was to determine whether variations in the measurements of this radiation which had been observed previously were due to actual changes in the intensity of the radiation or to instrumental or other factors. It was found that, although a definite tendency of variations common to all three instruments occurred, there were, however, considerable changes which were characteristic of the individual instruments. This matter apparently requires further study before such measurements can be placed on an entirely satisfactory basis. The comparison of one of these instruments with those of Millikan was designed to give a relation by which the measurements at sea and those of Millikan might be reduced to a common basis. The approximate residual-ionization of the two Kolhörster-type instruments was redetermined by immersion in a fresh-water lake near San Francisco. Gish, Parkinson, Jones, and Seaton participated in this work.

Equipment for recording air-potentials and also both positive and negative conductivity was installed at the Tucson Magnetic Observatory of the United States Coast and Geodetic Survey by Wait during September and October. This equipment was inspected by Gish in October upon his return from Honolulu. He also took part in special tests and final adjustment of this equipment. Preliminary results indicate this site to be unusually free from those local effects so commonly encountered over land and which interfere with the study of aspects of wider significance. The conductivity here is considerably higher than the average of observations elsewhere, but the potential gradient is such that the air-earth current computed from these elements is close to the average of other stations (see p. 319).

In a preliminary trial of a recording field-station, Wait during August obtained at Penalosa, Kansas, records of potential gradient with an improvised recorder (see p. 318).

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[1] From report by chief of section, O. H. Gish.

While at Honolulu, Gish visited the United States Coast and Geodetic Survey Observatory at Ewa with the special purpose of ascertaining the suitability of this site for possible future work in atmospheric electricity and earth-currents. He also visited the Volcano Observatory on the Island of Hawaii and inspected the Kilauea Volcano and vicinity in order to better judge the feasibility of earth-resistivity surveys there and the likelihood of such surveys supplying more information regarding the electrical properties of the deeper-seated portions of the Earth's crust.

A table of constants of atmospheric electricity for inclusion in a new edition of the Smithsonian Physical Tables was prepared by Gish. A study of the deck-observatory potential-gradient reduction-factors was made by Gish and Sherman, and a method of adjusting and applying these determined upon for the five-year period 1924–1928. With the factors thus obtained, Sherman prepared final hourly means of potential gradient by months for this period and made Fourier analyses of these (see p. 305).

Data from both the Watheroo and Huancayo observatories bearing on variations of the conductivity scale-values and the potential sensitivity of the electrometers used in the conductivity-recorders were assembled by Sherman who, jointly with Gish, made a study of these variations as a function of temperature. It was found that both the resistance of the Bronson cells and the sensitivity of the electrometers are affected by temperature. The temperature-coefficient for the electrometer-sensitivity is generally smaller than that of the Bronson cell. This investigation was similar to that made by Wait for Watheroo (see annual report for 1928–29, p. 273), but since that time the sensitivity of the electrometers has been determined at the time of each conductivity-calibration, thus making possible a more precise determination of these temperature-coefficients (see p. 305).

As opportunity occurred, experiments were carried out by Sherman to determine the best methods of exploring an artificial electric-field, especially with a view to determining the distortion produced by models of structures for which a potential-gradient reduction-factor may be desired and for testing the action of radioactive collectors (see p. 304).

Earth-currents—Investigations of this subject during the year have been somewhat stayed by the pressure of other matters. Only minor matters pertaining to the measurements at the observatories required attention. The earth-current measuring-systems at both observatories appear to be functioning excellently. On account of the rather large variations in the earth-current potentials recorded on system III at Huancayo, one of the lines was shortened (see p. 283). Comparisons of the records from this shortened line with the corresponding records of system I were made by Rooney, who found the new arrangement more satisfactory in every way than was the old. From a study of the records obtained with the old and those with the new arrangement and the results of special resistivity-measurements, Rooney showed that the greater gradient obtained on system III was due to an area of high resistivity which was covered by the longer line but not by the shorter one.

While at Huancayo for the primary purpose of carrying out an earth-resistivity survey, Rooney, during the interval between the dry-season and wet-season resistivity-work, brought the earth-current scalings up to date and made some studies of these data. These studies have been completed since his return to Washington, February 4, 1930, so that, together with previous work, three years of earth-current records from Huancayo are now completely reduced and analyzed (see p. 303).

Further studies of earth-current storms were made by Gish and Rooney. Records for the storm beginning at 21^h G. M. T. July 31, 1929, from five stations (three in the Northern Hemisphere and two in the Southern Hemisphere) have been compared (for a preliminary account of this investigation, see p. 302). This study disclosed a remarkable feature of earth-current storms, namely, that the current is apparently everywhere flowing in nearly the same direction during certain stages of the storm. For example, at the commencement, which was sudden, the direction was approximately northwest.

Earth-resistivity—The earth-resistivity survey at Huancayo by Rooney was completed early in January 1930. Following his return in February to the office, the study of the data was completed and a general report prepared for publication by Rooney and Gish (see p. 312).

Miscellaneous—An increasing interest in atmospheric electricity has been manifested by the increased number of requests for general information and especially for instrumental details. Of the latter, a number have been for the Department's design of ion-counter. Several serious investigators conferred with members of the Section regarding atmospheric-electric methods with a view to making such measurements as part of investigations of factors affecting human health. The economic geophysicist has not been lacking among those who have manifested interest in terrestrial-electric matters—an interest varying from the most general to the very specific. One of the many supplied in the past few years with working drawings of the Department's resistivity-equipment designed by Gish gave effective expression to his appreciation of this assistance by communicating the results of some extensive work, obviously carefully done. The first surveys were over known oil-bearing structure and later surveys were made in connection with the extension of known oil-fields. The resistivity-method was used in conjunction with magnetic and gravity surveys and is considered by this party to give satisfactory indications in the particular field examined to depths as great as 2000 feet.

The Department continued in cooperation with various workers in atmospheric electricity. Apparatus for the measurement of conductivity during the solar eclipse of October 21–22, 1930, was provided A. Thomson, Director of the Apia Observatory, for use at the proposed station on Niuafou Island.

Sherman continued the preparation of quartz-fiber electrometer-elements for the Department and its observatories and those cooperating observers to whom apparatus is supplied.

A diurnal-variation series of nucleation count was made by Wait, Torreson, and Sherman, March 27–28, 1930 (see p. 320).

Publications—A paper entitled "A leak-free method of measuring air-potentials" by Gish and Sherman was completed early in the report-year. Gish read a paper on atmospheric electricty before the Philosophical Society of Washington on April 12 as part of a special *Carnegie* program. On April 15, Gish gave a lecture in the Institution's series entitled "Natural electric-currents in the Earth's crust." He also presented a paper on "The significance of atmospheric-electric observations at sea" before the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, May 2. A note on the relation to earth-current storms of certain electrical measurements on oil pipe-lines made as part of an electrolysis-survey by the Bureau of Standards and the cooperating parties was prepared by Gish. With Rooney he prepared a note on the earth-current storm which began at 21^h G. M. T. July 31, for which records have been obtained from several observatories. Rooney presented a paper before the Philosophical Society of Washington, March 22, entitled "Earth-resistivity survey at Huancayo, Peru, and relation of resistivity to earth-current potential-records." These and other investigations partially completed are briefly summarized in the last portion of this report giving abstracts of publications and investigations.

FIELD-WORK AND REDUCTIONS

IMPROVEMENTS AND COOPERATION FOR FIELD AND OBSERVATORY

As indicated in the annual report for 1928–29, the maintenance of the instrumental equipment, the development of new equipment, and the operations of the *Carnegie* made heavy demands both on the staff aboard the vessel and at the laboratory in Washington. The disaster which overtook the *Carnegie* while loading gasoline in Apia Harbor, resulting in the complete destruction of the vessel and her equipment, in the deaths of Captain Ault and Cabin-Boy Kolar, and in injuries to five of the sailing staff, added materially to these demands on the personnel at Washington. This has been especially the case since it has been deemed desirable in the interest of the development of oceanographic work that the data obtained on the *Carnegie* in oceanography particularly should be promptly revised, discussed and published.

The salvaging of non-magnetic metals, chiefly lead ballast and brass and bronze of the mechanical equipment, was a task of no small size carefully handled under Parkinson's management in several months' stay at Apia and which would have been much more difficult had not local residents and government officials been so generous in their assistance. The Administrator and his associates in the Government of Western Samoa, the Governor and his officers in American Samoa, the United States Navy Department, and the port authorities and Messrs. Snow and Company of San Francisco, California, have each and all done much to lighten the tragedy and the difficulties of caring for the injured and uninjured members of the scientific and sailing staffs. Without this aid some of the difficulties, so enhanced by the great distance of Apia from Washington, would have been well nigh insurmountable and certainly would have greatly prolonged the distress attending the accident.

The reductions of the oceanographic work of the *Carnegie* have been particularly facilitated by residence at Washington from early in March of Sverdrup, on furlough from the Geophysical Institute of Bergen. With the assistance of Soule, Ennis, Scott, Kolar, and Seaton, he completed so large a part of the revisions and discussions of the oceanographic data that at the end of the report-year the materials for the tables of results were in such shape that the preparation of manuscript might soon thereafter be undertaken, as also the preparation of graphical representations of the data accumulated. In connection with this work, it has been necessary to consider and give careful attention to the questions concerned with the accuracy of the various determinations made on board. It is a fine commentary upon the management of Ault in this work and upon the interest and whole-hearted cooperation with him on the part of the staff on board that Sverdrup, who has had an unusually wide experience in the discussion and compilation of similar oceanographic data on many expeditions, finds that the quality and quantity of the work done is second to none—a statement applying not only from the scientific viewpoint but also from that of cost. Among the memoranda already prepared are the following: "On the accuracy of the subsurface-water temperature-observations on board the *Carnegie*"; "Regarding the corrections of reversing thermometers determined in August 1929"; "On the depth of bottom-samples from stations 37 to 87 of the *Carnegie*"; "On the accuracy of the thermometric determination of depth on board the *Carnegie*"; "On the determination on board the *Carnegie* of depth at which temperatures were measured and from which water-samples were collected."

Simultaneously with the preparation of the above, the necessary computations for the discussion of the results have been carried on and several papers relating thereto have been prepared by Sverdrup including "Some oceanographic results of the *Carnegie's* work in the Pacific—The Peruvian Current" presented before the American Geophysical Union, May 1, and "The deep-waters of the Pacific according to the observations of the *Carnegie*" prepared for presentation to the Stockholm Assembly of the International Geodetic and Geophysical Union. These and other papers prepared by members of the staff are abstracted in the last section of this report dealing with publications and investigations. Paul has prepared, in similar style to those by Ault for the cruise as far as Callao, progress-letters on the passages from Callao to Tahiti, from Tahiti to Apia, from Apia to Yokohama, from Yokohama to Honolulu via San Francisco, and from Honolulu to Apia, and had nearly completed at the end of the year a descriptive and narrative account of the expedition.

Naturally the loss of the *Carnegie* and the infeasibility of the Institution's providing funds to build another like non-magnetic ship, especially since the distribution-survey of terrestrial magnetism over the ocean may be considered to be completed by the 20 years of actual cruising of the *Carnegie* and of her predecessor, the *Galilee,* have raised important questions on ways and means of obtaining future magnetic and electric observations at sea. A committee consisting of Peters, Soule, and Torreson, the first of whom has taken so outstanding a part in the successful development of the Department's work over the oceans, considered such ways and means that might be helpful in the development of plans for oceanographic research with occasional magnetic and electric observations. The recommendations of the committee's report may be summarized as follows: (1) Preparations by the Department to reproduce the magnetic and atmospheric-electric instruments for use at sea at the earliest possible moment; (2) prompt publication of the results of Cruise VII with special reports for the use of future expeditions; (3) the immediate preparation and distribution of various memoranda regarding experience acquired on the *Galilee* and *Carnegie* with suggestions for improvements of methods, instruments, conditions, etc.; (4) cooperation with proposed oceanographical expeditions of other organizations to secure observations in magnetism, atmospheric electricity, or other physical phases of oceanography when the construction of the ship is found suitable for such work; (5) the advocation of an endowment sufficient not only to purchase but keep in practically continuous commission a vessel suitable for every phase of scientific research at sea. The report is accompanied by eight appendices as follows: The determination of geographical position for scientific observations at sea and especially in connection with magnetic work, by Torreson; On the program for future magnetic measurements at sea, by Torreson; Notes regarding oceanography, by Soule; Pilot-balloon ascensions at sea, by Torreson; Proposed plan for atmospheric-electric measurements on an expedition making scientific measurements at sea collaborating with Department of Terrestrial Magnetism, by Torreson; The biological and chemical program, by Graham; Radio aboard the *Carnegie,* by Seaton; On the possibility of using available vessels for determining magnetic secular-variation, by Peters. A report preliminary to the above was also prepared by the committee on the requirements for a vessel suitable for magnetic work associated with other oceanographic investigations. Copies of these reports have already been distributed to organizations and individuals interested in forwarding oceanographic investigations.

The results above noted in oceanography may appear concentrated upon the discussion of the data obtained in the Pacific. It is to be remarked, however, that the oceanographical work of the vessel done in the North Atlantic and now being reduced and compiled gives pertinent information on the character of the water-circulation in that ocean to a depth of 2000 meters. Some of the *Carnegie* stations are situated in well-known areas and there the results are found in excellent agreement with those of other expeditions. The greater number of the *Carnegie* stations are to the west of the explored areas, and charts representing the currents which are due to the distribution of density can now be extended to the 50th meridian west. The *Carnegie* data show that in latitude 40° north and longitude 50° west the Atlantic drift—the continuation of the Gulf Stream—is divided into two branches, one continuing northerly across the Atlantic Ocean and one southerly forming part of the anticyclonic circulation of the Sargasso Sea region. To the south of the Sargasso Sea the data demonstrate the existence of the trade-wind drift, which continues in part into the Caribbean Sea and in part turns towards the northwest to the east of the West Indies.

Notable contributions have resulted from the *Carnegie's* chemical program. Preliminary reports based on the results have already been prepared and forwarded for communication before the meeting of the International Section of Oceanography in Stockholm in August 1930. Among these may be mentioned the following: "The distribution of oxygen in the Pacific as an index of the circulation of the water" by Moberg and Graham; "The phosphate-content of the surface-water in the Pacific as related to the circulation" by Moberg, Seiwell, Graham, and Paul. In this connection, it is noteworthy that the conclusions drawn in these two papers regarding the waters in the Pacific substantiate in all major details those made entirely independently from consideration only of the physical oceanographic data referred to above.

The electrical apparatus for the determination aboard ship of the salinity of sea-water by the conductivity-method has amply demonstrated its feasibility and value, and a long communication under the title "Apparatus for the determination aboard ship of the salinity of sea-water by the electrical conductivity-method" has been prepared for the Stockholm Assembly by Frank Wenner of the United States Bureau of Standards, Edward H. Smith of the United States Coast Guard, and Soule of the *Carnegie's* staff (see p. 321).

The 82 bottom-samples collected by the *Carnegie* were arranged and separated for distribution by Graham and forwarded, together with memoranda regarding their collection, depths, geographic positions, and field notes, for study and report by the Scripps Institution of Oceanography, by the Frick Chemical Laboratory of Princeton University, by Dr. Albert Mann of the Carnegie Institution of Washington, and by the Geophysical Laboratory of the Carnegie Institution of Washington; in addition, eighteen typical specimens were selected and forwarded for deposit at the Carnegie Museum of Pittsburgh. Graham has completed the preliminary arrangements for the distribution of the plankton and other biological samples accumulated. In this connection, it is of interest to note that specialists in the various branches of marine biology have been most helpful in suggestions and ready in offers to undertake the examination and classification, and to report on these samples as regards the field of each. It is expected that the distribution will be made accordingly before December 1930.

The installation of the Meinesz gravity-apparatus at San Francisco in August, preceded by careful tests in cooperation with the United States Coast and Geodetic Survey at Washington, was carefully made by F. E. Wright of the Geophysical Laboratory of the Institution who returned from Europe so that he might do this. He was assisted in this by Peters and Forbush. While the results obtained before the accident were not good, much promise of eventual improvement was evident (see p. 301). A most important contribution to this work was the cooperation of the United States Naval Observatory through its superintendent, Captain Freeman, throughout all stages and later in the reductions of those records which are judged sufficiently good to give reliable results.

The whole-hearted cooperation of our own governmental departments, individuals, and private organizations, and of those abroad has been brought home forcibly by the actions taken in almost every case, relieving the Institution of any financial burden by reason of the losses occasioned by the disaster to the *Carnegie* in equipment, books, and appurtenances that had been loaned for the use of the expedition. These agencies and individuals are so numerous as to prohibit making individual mention.

COOPERATION WITH OTHER ORGANIZATIONS

In addition to the extensive cooperation above indicated in the ocean work of the *Carnegie*, it may be mentioned that those cooperative endeavors listed on pages 220 and 221 of last year's report have all been continued. The coordinated efforts of the United States Coast and Geodetic Survey, the Alaska Agricultural College and School of Mines, and the Department to establish a first-order auroral station at the College near Fairbanks, Alaska, have been realized through the generosity of the Rockefeller Foundation in providing funds for a five-year program submitted through the Department. The cameras for photographic observations were promptly ordered, tested by Störmer and his colleagues at the observatory in Norway, and forwarded through our Department to Fairbanks, where they were received in time to do some experimental work in the past winter so as to pave the way for the active campaign of observation next winter.

The safe return of the Byrd Antarctic Expedition and of the records of the valuable series of magnetic and auroral observations secured at the base-station in Little America is noted elsewhere in this report—there can be no doubt that these will afford valuable additions to the few available antarctic data.

Preliminary plans have been made to cooperate in some degree with the proposed arctic expedition of Wilkins in a submarine in 1931, with that of "Aeroarctic" in a dirigible also in that year or in 1932, and with the plan for a Jubilee Polar Year in 1932–33 now being so vigorously developed under the capable chairmanship of D. la Cour of Denmark.

OCEAN WORK[1]

PROGRESS-REPORT OF CRUISE VII, JULY TO NOVEMBER 1929

The following is extracted from Captain Ault's reports on the progress of the seventh cruise of the *Carnegie*, which was so tragically ended in the catastrophe to the vessel and the deaths of Captain Ault and Cabin-Boy Kolar, November 29, 1929, in Apia Harbor. At the beginning of the report-year the *Carnegie* was in latitude 38° 30′ north and longitude 147° 30′ east en route from Yokohama to San Francisco.

"After leaving Yokohama June 24, 1929, the first ten days were featured by light variable winds and calms. The engine was operated frequently and the average day's run was about 90 miles. Advantage was taken of a smooth, calm sea on June 27 and 28 to swing the vessel for deviations. One helm for declination-observations was made on June 27 before the clouds covered the Sun; all the next day was spent in making a swing with both helms for inclination and horizontal intensity.

"About July 4 the region of cold surface-water was entered with practically one hundred percentage of clouds, mist, fog, drizzle, and rain, which continued until July 20. The wind was somewhat stronger, but not favorable. Adverse winds during July 9 to 12 drove the vessel 300 miles to the southward of the proposed track and the weather was so cold that the copper stove was used in the cabin from July 5 to 26. On July 14 the wind freshened from the southwest and for ten days the average daily run was about 200 miles. Better weather was met between July 22 and 29, the wind still continuing fair and strong.

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[1] From the reports of the chief of section and commander of the *Carnegie*, J. P. Ault, and of senior officer in charge of the *Carnegie* party returning from Samoa to Washington, F. M. Soule.

"During the cloudy, foggy weather the program for declination was sadly interrupted. No observations could be obtained on July 6, 7, 12, 13, 14 (I) and 19. On some of the other days, the observations were made with the Sun at such high altitudes and with such rough seas that the accuracy was seriously impaired. During the same period no balloon-flights could be made. The alternation of ocean-stations with magnetic stations was maintained throughout the trip, except that July 14 (II) and 15 were interchanged, on account of strong wind and rough sea. The ocean-station on July 15 was not successful below 500 meters. The messengers would not reverse the bottle owing to large wire-angle. For the later stations with strong wind, 170-pound lead weights were used on the end of the bottle wire, and the newer and heavier messengers were made still heavier by filling two drill-holes with lead, bringing the weight per messenger up to 13 ounces, as against 7 ounces for the ones previously used. These changes permitted securing temperatures and salinities down to 3500 meters with wind-force 6.

"The sonic-depth program was carried out as usual by Soule, Jones, and Paul. Some difficulty was experienced, owing to noisy microphones during high speed of the vessel through the water. No unusual variations in the depths were noted, except that on July 24 some irregularities were observed, indicating the existence of several surfaces and some rapid changes in depth.

"Tests with the new balloon sextant-theodolite-chair gave good results. The azimuths given by the chair differed from the regular theodolite by 1°5 with an extreme range of 5° in thirty-five readings. A few improvements and more experience will decrease this range. Thus in rough water, when the balloon becomes lost to the observer at the theodolite the observer at the sextant can carry on until the balloon disappears. Even now when the observer at the theodolite loses the balloon for a moment a glance at the azimuth-circle of the chair gives him the approximate theodolite-readings and enables him to relocate the balloon.

"The first ocean-station after leaving Yokohama required seven hours to complete. Owing to strong currents the piano wire fouled the bottle wire and required some time and care to untangle and to avoid breakage and loss of wire, thermometers, and snapper. The current took the wires underneath the vessel, and the piano wire caught on the oscillator also. In an effort to locate and remedy the trouble the "divinhood" was used, but the rolling of the vessel made the attempt dangerous on account of liability of helmet to be lifted off the head. However, sufficient depth was reached to show the trouble and a lead weight was then lowered along the piano wire, thus clearing it from the oscillator.

"The new scheme of leaving the lead weights at the bottom has increased the efficiency of the bottom-sampling and decreased the time required. The 60-pound weight is in two halves, and each is suspended by a wire from the hook on the Sigsbee releasing-device which has been installed on the end of the shaft of Ross-type snapper. The bottoms of the two weights are fastened together by two staples driven in fairly tight. When the snapper hits bottom, the hook releases the wires allowing the two weights to fall apart outward from the top, thus forcing the lower staples out and the weights fall free. The snapper is driven into the ground with such force by the 60-pound weight that it has never failed to release the catches and it has come up full and closed. At two stations, the snapper was sent down twice, and was successful each time. On account of drift and limited length of wire, no bottom-sample was attempted on the days of high wind and rough seas. There is an economy of time, power, and personnel in using the main winch for the bottom-sampling instead of a separate machine. The only delay is on occasions when the pump could come up sooner but must wait until the bottom-sample is ready to come up.

"The atmospheric-electric work by Parkinson and Torreson has suffered some interruption because of bad weather, particularly in the few eye-reading diurnal-variation runs obtained. Unusually good potential-gradient traces, however, were secured, in spite of the foggy, misty, rainy weather.

"Radio conditions were good and schedules were maintained every night. Exceptional cooperation has been shown by our amateur friends, and especially by the 'San Francisco Examiner' radio station KUP.

"The following observations were made during the period June 24 to July 29: 40 declinations, 18 inclinations and horizontal intensities, 2 atmospheric-electric runs, 26 complete potential-gradient traces, 12 pilot-balloon flights, 17 ocean-stations, and 166 sonic depths.

"During the stay in San Francisco from July 28 to September 3, new supplies and equipment were obtained and repairs were made to sheathing and machinery. Apparatus after Meinesz for gravity-determinations at sea was installed with the assistance of Wright (Geophysical Laboratory) and Peters. On July 31 the vessel was swung for deviations on both helms. Complete swings were made for declination and horizontal intensity using deflector 5. A swing on one helm was made for horizontal intensity using the earth inductor and another was made for inclination. A land station was operated on Goat Island during these swings. The magnetic station at Fort Scott was reoccupied and deflector 5 was again standardized. Special tests of penetrating-radiation apparatus were carried out by Gish, Parkinson, Jones, and Seaton (see p. 260). A recording conductivity-instrument was installed in San Francisco and thoroughly tested on the trip to Honolulu by Gish and Parkinson. Other atmospheric-electric instruments were remodeled and tested. Gish and Parkinson also made daily comparisons of two Kolhörster-type penetrating-radiation instruments with the *Carnegie* instrument between San Francisco and Honolulu.

"Exercises commemorating the twenty-fifth anniversary of the inauguration of the Institution's research activities had been arranged to be held on board the *Carnegie* at San Francisco Harbor. These exercises, held August 25, 27, and 28, were well attended, there being about 150 specially invited guests present on the first day and over 2500 persons took advantage of the opportunity to inspect the vessel during the three days. Weather conditions were ideal throughout—even for California. At the special exercises on the afternoon of August 26, W. B. Storey of the Board of Trustees presided, and the following addresses were delivered: 'The Carnegie Institution's program as originating with Mr. Carnegie' by Dr. Henry S. Pritchett, Vice-Chairman of the Board of Trustees; 'The contribution of research' by Dr. W. W. Campbell, President of the University of California; 'The Department of Terrestrial Magnetism's contribution to our knowledge of the physics of the Earth' by Ault; 'Program of the Institution in physical sciences with special reference to astronomy' by Dr. Walter S. Adams, Director of Mount Wilson Observatory. A specially printed pamphlet prepared in Washington, giving details regarding the Institution and a popular account of the problems and research work occupying the attention of the Department on land and sea with a description of the *Carnegie* and her equipment, was distributed during the exercises.

"At San Francisco, Forbush relieved Torreson, Seaton relieved Jones, and Graham was taken on to fill the place vacated by Seiwell at Apia. Gish accompanied the vessel from San Francisco to Honolulu for special work in atmospheric electricity. E. G. Moberg of the Scripps Institution of Oceanography at La Jolla also made the trip from San Francisco to Honolulu on the *Carnegie*.

"The entire trip of twenty days from San Francisco to Honolulu was featured by light airs and calms, with only a few days of regular trade-wind, the northeast trade-wind not appearing until September 17. The extremes in daily runs were 66 to 177, average being 108.8 miles. The engine was used frequently. The new ball-bearing friction band on the winch installed at San Francisco has proven entirely successful. Several deep water-bottle series were sent down and brought up without any overheating or difficulty.

"The new pelican bottom-snapper was successful on the first trial. On another occasion apparently it struck a whale at about 500 meters. On two occasions the spring was not tight enough and the pressure of the water on inside of jaws as snapper went down rapidly was sufficient to open them, allowing the tongue catches to fall down closing the snapper, so that it struck bottom after being closed. Enough mud was secured from the outside of the jaws to examine for classification. The snapper came up full on four occasions, yielding about one and one-quarter liters of material, one sample weighing nearly two kilograms. It is expected that 100 per cent efficiency with this snapper will be had after final adjustments.

"A peak or mountain which existing charts show at 32°2 north and 128°2 west, with a depth of fifty-eight hundred feet of water over it, was relocated thirty miles northeast of the above position, or at 32°4 north and 127°8 west, and with a least depth of forty-six hundred feet. It was named Hayes Peak in honor of Dr. Harvey C. Hayes of the Naval Research Laboratory, Washington, D. C., who developed the sonic depth-finder for the United States Navy. The slopes of the peaks are very steep, dropping off over eighty-five hundred feet in six miles. The peak rises out of a general depth of over fourteen thousand feet. Thus the peak is about ten thousand feet in height. The absence of soundings south and east leaves open the possibility that it may be a ridge instead of an isolated peak.

"The new balloon-theodolite received at San Francisco is a decided improvement over the first one. The larger field of view permits keeping the balloon in sight continuously until it disappears due to distance. The new sextant-chair was used on several occasions to extend the time of observed flight, going to 59 minutes on one occasion. As the supply of six-inch uncolored balloons was low, it was necessary to use black on several occasions, but their visibility was so poor that nine-inch uncolored balloons were used after that.

"The regular program of observation was carried out and included 10 ocean-stations, 9 stations for dip and intensity, 27 stations for declination, 96 sonic depths, 11 potential-gradient and 10 conductivity traces, 14 pilot-balloon flights, and 4 evaporation-series.

"The vessel arrived at Honolulu at noon, Monday, September 23, after an unusually quiet approach the previous night. The passage from San Francisco covered 2186 miles.

"Leaving Honolulu, October 2, under tow, sail was set in a fair wind when three miles off the entrance to the harbor. For five days winds were fairly strong and favorable, from the east and northeast. On October 7 the trade-wind went light and on the eighth it shifted to the southwest. The wind continued from the westward until October 18, when it shifted to the east and with only slight interruptions remained in that quarter until Pago Pago was reached.

"More calm days were experienced than usual, the engine being used for a total of about 260 hours. It performed well and saved many days' delay. No storms were encountered, although many days were rainy and squally. The weather was ideal for ocean-work.

"The usual program of ocean-work by Ault, Soule, Graham, and Paul, and magnetic work by Soule, Forbush, Scott, Seaton, and Ault was carried out without interruption. The track as outlined was followed closely with two exceptions, where the wind was unfavorable. During the 48 days at sea, 73 declination-stations, 23 stations for inclination and horizontal intensity, and 23 ocean-stations were occupied. The usual atmospheric-electric program was carried out, the new conductivity-recorder performing in excellent manner. Four diurnal-variation runs were made by Parkinson and Forbush. During the ocean-stations much loss of equipment was suffered, by accident, by wearing out, and because of unusually heavy cross-currents in the region of the Equatorial and Counter Equatorial Currents. On October 11, the tow-net wire jumped off the sheave and wore through, and two silk nets, half-meter size, were lost. Also the piano wire parted at 2400 meters, due to splice slipping and jamming under guard-nail on meter-wheel. Two nails were installed on meter-wheel to keep wire from jumping off when being paid out. These nails were supposed to be removed when reeling in the wire; had this been done, the wire would not have jammed and parted. A Sigsbee-Ross snapper and modified Coast and Geodetic Survey reversing-frame, with two thermometers P. T. R. Nos. 160 and 870, were lost. One of the new Ludwig-Andersen reversing-frames was then placed in service for bottom-temperatures and, after some adjustment, has given good satisfaction.

"To avoid further loss of tow-nets, the rubber shock-absorber rope has been used off the forecastle head since October 13, thus eliminating use of blocks. On October 15 the 5-mm. bottle wire began to break, having been in use since Guam. A new reel was installed on October 17. To provide data on chemical-content from deeper levels, water-bottles were sent down to 4500 meters frequently; this is about the limit for the 4-mm. wire, due to the strain of weight, bottles, drift, etc. On October 19 the bottles of the deep series were not reversed, due to messenger being entangled in a mass of rope-yarn which someone had thrown overboard. On October 25, due to unusual currents, the piano wire aft fouled the bottle-wire, starboard. In an attempt to clear them, the bottle-wire fouled the outboard platform. Without giving the matter much thought, the wire was given a kick to clear it. The terrific strain of nine bottles, 4200 meters of wire, and the drift on the wire caused the metal edge of the platform to cut the outer strands and so injured the whole wire that it parted when the attempt was made to haul it in. Thus 4200 meters of new 4-mm. aluminum-bronze wire, nine Nansen water-bottles, nine brass messengers, and 18 Richter and Wiese deep-sea reversing thermometers (P. T. R. Nos. 163, 2996, 201, 159, 162, 2995, 502, 200, 586, 909, 504, 2994, 506, 1696, 161, 908, 203, and 866) were lost. The 2000 meters of new 6-mm. aluminum-bronze wire were spliced to the remaining 2000 meters of new 4-mm. wire, using a bottle just above the splice, with messenger hanging below the splice on a long wire. Thus the strain of a deep-series comes on the 6-mm. wire, and this should last for some time. Fortunately there were on hand sufficient new Nansen water-bottles, but the supply of reversing thermometers made it difficult to meet the emergency. On October 29 it was necessary to use the bottle-wire on the lee side to avoid wire leading under the vessel, due to heavy current against the wind. On October 31 the short bottle-series fouled the pump-wire. The pump-wire was hauled under the vessel from starboard to port, when the heavy current cleared the wires and all were brought up without damage.

"To avoid tangling of wires from the quarter-deck, the program was now modified, sending down the bottle-series first and then the piano wire. In spite of this, on November 4 the unusual currents trailed the tow-nets aft from the forecastle head far enough to foul the bottle-series, stripping off two thermometers (P. T. R. Nos. 4258 and 3379) from bottle *X*. No other damage was done.

"Sixteen bottom-samples were secured out of 19 attempts. The Sigsbee-Ross snapper was used until October 15; thereafter Pelican No. 1 with large jaws was used with fair success. Twice it brought up only small fragments of black lava cinders. Five times it was full, and twice it was only half full. A small black nodule was caught between the jaws on one occasion, preventing jaws from closing, and only a cupful of material remained. On November 8, no attempt was made to secure a bottom-sample. The bottom-bottle *Y* of the deep-series was sent down to 4000 meters, the sonic depth-finder having determined the depth as 5200 meters at 7.30 a.m. When *Y* was brought up and the water-sample was being removed, a small amount of globigerina-ooze was found inside the bottle, showing that it had been on the ocean-floor. The depth was immediately measured again with the depth-finder, confirming the shoaling of 1200 meters in a few miles. At the ocean-station on November 6 (latitude 1°8 south) the bottom-sample was globigerina-ooze, the first secured since leaving the South Pacific.

"Bottom-temperature was secured 14 times, ranging in value from 1°8 C. at the depth of 2770 meters to 1°65 C. at 6184 meters (latitude 32°7 north, longitude 160°7 west), and to 1°08 C. at 5522 meters (latitude 13°6 south, longitude 168°4 west). On November 17, after three-days' calm, the surface-temperature was 28°6 C., while that at a depth of 5 meters was only 27°8 C. The usual difference has been on the order of 0°01 to 0°02, thus showing the mixing effect of winds.

"Ocean-depths were measured 274 times with the sonic depth-finder, this instrument continuing to function well. Much new information on bottom-contours was obtained. A new peak 7000 feet above the general level was discovered on October 4 at 25°6 north, 160°3 west. The slopes were not developed, so it has not been named.[1] A second sounding nine miles later gave 5900 feet deeper. In the vicinity of 14° north, 136° west, the ocean-floor was very irregular, depths changing 1500 meters in nine miles.

"The slopes of Penrhyn and Manahiki islands, as well as on the approach to Tutuila, were determined with frequent soundings by Soule, Paul, and Seaton.

"The chemical and biological program has been carried on with a high degree of efficiency by Graham and Paul. Oxygen-content has been determined at each ocean-station, and an additional vertical tow-net haul has been made from a depth of 150 meters. The Pettersson plankton-pump continues to function with considerable persuasion, adjustment, and repairs by Paul.

"The pilot-balloon flights have been observed by Forbush, Scott, and Paul. With the new theodolite little use has been required for the new sextant-azimuth chair. The conditions have been favorable also as regards

[1] This peak has been named Ault Peak in memory of Captain Ault.

rolling of the ship. Thirty-two flights were made between Honolulu and Pago Pago.

"On November 10, a stop of nine hours was made at Penrhyn Island to collect diatoms, measure gravity, and for recreation. The vessel remained hove to off West Pass, and two gravity-runs were made. Conditions were about as smooth as though we had been anchored in the lagoon. The party had lunch on shore with Resident Agent Wilson and the traders Wilkinson and Woonston.

"On Tuesday, November 12, a stop of five hours was made at Manahiki Island for the same purposes. Here the wind was more parallel with the shore and the conditions for the gravity-measurements were not so good. Resident Agent Williams showed us around his unusually clean and neat village, and had the young people stage for us a Manahiki dance. It was perhaps the most unique and interesting of any south-sea dancing, with the possible exception of the Samoan siva-siva.

"The last four days before reaching Pago Pago were calm and the engine was operating. Fortunately we had sufficient gasoline remaining to reach Pago Pago without delay. We docked on November 18, after 47.5 days at sea. The distance logged was 5777 miles, giving 121.6 miles as the average run per day.

"Seaton has maintained daily schedules with nine stations in the United States, with frequent contacts in Honolulu, Philippines, Australia, New Zealand, etc. The press-reports have been very noticeable by their interest and frequency. Seaton has spent considerable time improving his equipment and in daylight experiments.

"It is a great pleasure to record a tribute to the newly constituted party and to the zeal and cooperation and attitude of helpfulness shown by each member of the staff. The program is so strenuous, each man has so much to do and works under so much pressure, that the work would not be accomplished without this spirit of comradeship."

The above accounts of the passages of the cruise during July 1 to November 18 are the last received from Captain Ault, as he lost his life November 29 in the disaster at Apia. The remarkable quantity and quality of the results obtained on Cruise VII were due to his executive ability combined with his own industry and the interest with which he enthused all the ship's personnel. The words of the preceding paragraph—concluding Captain Ault's last written report—express better than any other commentary the underlying reasons for the success attending the work at sea.

The short stay in Pago Pago was devoted chiefly to taking on supplies, including about 2000 gallons of gasoline.

On the afternoon of November 27, the *Carnegie* left Pago Pago for Apia, Western Samoa, where she arrived early the following morning. Here additional gasoline (2000 gallons) was to be taken aboard to complete filling of the storage tanks, the supply available at Pago Pago having been insufficient. It was shortly after 1 p.m. on Friday, November 29, when the storage was nearly finished, that an explosion occurred below decks. As a result of this explosion and the ensuing fire, Captain J. P. Ault, master of the vessel and scientific leader of the Expedition, and Cabin-Boy Anthony Kolar lost their lives, the engineer, mechanic, and three seamen were injured, and the *Carnegie* with all her equipment was destroyed.

TABLE 1—*Summary of ship's log and of magnetic, atmospheric-electric, and associated meteorological observations, Carnegie Cruise VII*

Run	Abstract of ship's log						Magnetic Stations		
	Departing	From	Arriving	At	Distance	Days at sea	*D*	*H*	*I*
	1928-9		*1928-9*		*miles*				
1	May 11	Newport News	Jun 9	Plymouth	3,669	29 3	29	12	11
2	Jun 18	Plymouth	Jun 22	Hamburg	614	4 1	2	2	2
3	Jul 7	Hamburg	Jul 20	Reykjavik	1,329	13 0	11	6	6
4	Jul 27	Reykjavik	Sep 16	Barbados	5,715	51 8	76	25	25
5	Oct 1	Barbados	Oct 11	Balboa	1,361	9 7	15	5	5
6	Oct 25	Balboa	Dec 6	Easter Island	4,788	41 9	58	19	19
7	Dec 12	Easter Island	Jan 14	Callao	3,334	32 9	38	15	15
8	Feb 5	Callao	Mar 13	Papeete	4,470	35 8	63	17	17
9	Mar 20	Papeete	Apr 1	Pago Pago	1,274	12 2	20	6	6
10	Apr 5	Pago Pago	Apr 6	Apia	80	0 8			
11	Apr 20	Apia	May 20	Guam	3,914	28 8	49	13	13
12	May 25	Guam	Jun 7	Yokohama	1,447	13 2	20	6	6
13	Jun 24	Yokohama	Jul 28	San Francisco	4,839	34 9	40	17	17
14	Sep 3	San Francisco	Sep 23	Honolulu	2,186	20 1	27	9	9
15	Oct 2	Honolulu	Nov 18	Pago Pago	5,777	47 2	72	23	23
16	Nov 27	Pago Pago	Nov 28	Apia	80	0 8			
	Totals				44,877	376 5	520	175	174

Run	Atmospheric-electric observations[a]											
	Potential gradient			Ionic content			Conductivity			Mobility		
	D-v series		Program	D-v series		Program	D-v series		Program	D-v series		Program
	A	*B*		*A*	*B*		*A*	*B*		*A*	*B*	
1			16			15			20			14
2												
3			5			9			9			9
4	21[b]	17[b]	35	6	1	36	6	1	38	6	1	36
5	4	5			1	5		1	6		1	5
6	24	7		1	1	10	4		33	1	1	10
7	24	9		4		23	4		24	4		23
8	23	7		3	1	26	3	1	26	3	1	26
9	1	4			2	8		2	9		2	8
10												
11	15	13		1	1	10	2		10	1	1	10
12	5	8		1		9	1		9	1		9
13	26	6			2	17	2		17		2	17
14	11	4			1	18	6[c]	12[c]	18		1	18
15	41	9		4		30	50[d]			4		30
16												
Tot.	195	89	56	20	10	216	78	17	219	20	10	215

[a] The series indicated in column *A* are "complete series" while those in column *B* are "incomplete series." A day on which not more than 2 consecutive hours were missing with a total of such omissions not exceeding 4 hours in the 24 is counted as "complete"; for potential gradient a "complete series" implies also one in which there was no negative potential in 24 hours.

[b] Including under *A* one and under *B* three eye-reading series, all other diurnal-variation series in potential gradient being from photographic records.

[c] Of these 6 are "complete" and 11 are "incomplete" photographic records.

[d] Of these 46 are "complete" photographic records.

TABLE 1—*Summary of ship's log and of magnetic, atmospheric-electric, and associated meteorological observations, Carnegie Cruise VII*—Continued

Run	A-e observations			Associated meteorological observations							
	Penetrating rad'n			Relative humidity			Condensation-nuclei			Evaporation	Balloon flights
	D-v series		Program	D-v series		Program	D-v series		Program		
	A	*B*		*A*	*B*		*A*	*B*			
1			11			19			19		
2											
3			15			22			22	1	
4	7	1	35		1	34		1	34	10	
5		1	7		2	6		2	6		
6	4		29	4		29	4		29	9	24
7	4		23	4		25		2	17	6	12
8	2	2	25	3	1	30	3	1	29	9	35
9		2	9		2	9		2	9	2	10
10											
11	2		10	2		13	2		13		20
12	1		10	1		12	1		12		9
13	2		34	2		29	2		26		12
14			17			17			18		17
15	4		37	4		50	3	1	33	1	32
16											
Total	26	6	262	20	6	295	15	9	277	38	171

TABLE 2—*Summary of ship's log and of oceanographic stations, Carnegie Cruise VII*

Run	Series[a]	Phys. and chem.	Biological[b]				Sonic depths	Bottom samples
			Net	Pump	Surface	Samples		
1	6	6	8		7	49	58	1
2		[c]			[c]			
3	2	2[d]	2		4[d]	10	40	1
4	22	22	22	21	7	129	205	6
5	4	4	4	3		19	29	1
6	19	19	20	18	14	116	71	10
7	17	17	17	16	23	118	73	13
8	17	17	17	17	2	88	210	15
9	6	6	6	5	1	26	64	
10							6	
11	14	14	14	14	1	86	159	3
12	5	5	5	5		32	50	5
13	17	17	19	16	2	103	166	7
14	10	10	12	10	24	75	96	9
15	23	23	23	23	23	163	272	16
16							1[e]	
Total	162	162	169	148	108	1014	1500	87

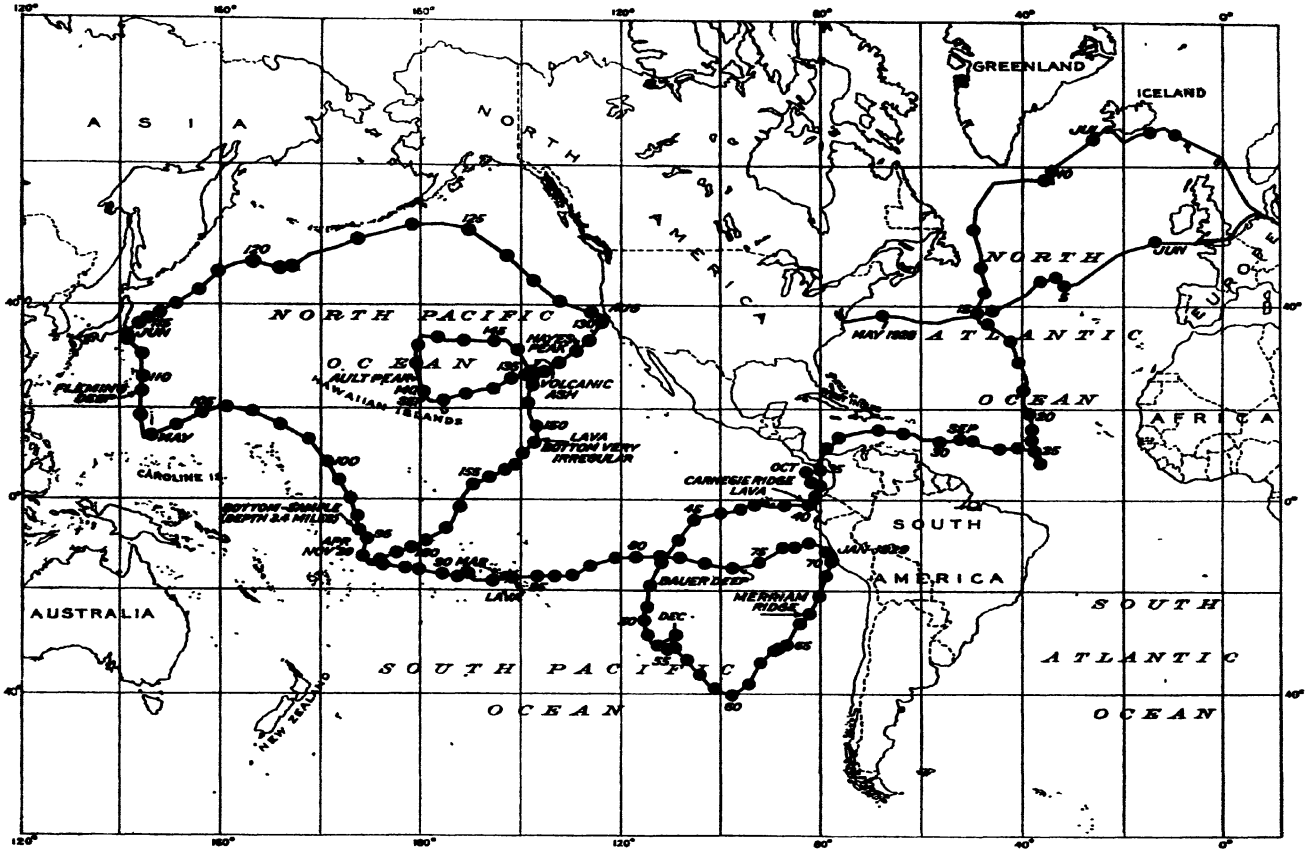
[a] Salinities and temperatures were obtained approximately at the following depths: 0, 5 25, 50, 75, 100, 200, 300, 400, 500, 700, 1,000, 1,500, etc., down to bottom or to maximum of 6,000 meters.

[b] Samples were obtained usually at 0, 50, and 100 meters.

[c] There were also 35 surface physical and chemical stations.

[d] There were also 38 surface physical and chemical stations.

[e] Record lost with the *Carnegie*.



Cruise VII of *Carnegie*, May 1, 1928, to Nov. 29, 1929, and Locations of Series-Stations for Oceanographic Observations.

(This cruise added 51,800 statute miles to the 291,000 covered during the first six cruises of the vessel between 1909 and 1921—a total of 343,000 miles in all oceans; the arrows point to locations of the more salient discoveries of the cruise.)

The results achieved during the finished portion of the cruise are significant scientific contributions not alone, as for past cruises, to terrestrial magnetism and electricity, but in particular to oceanography. The oceanographic data obtained are of such pioneer character for the Pacific and so fully justify the plans and expectations, from interpretations already made from them regarding the circulation and chemistry of the Pacific, as to emphasize how great the contribution has been to oceanography, and also the potential loss to that science by reason of the disaster so untimely interrupting the original plan for the cruise when it was scarcely half completed.

The accompanying map and Tables 1 and 2 summarize the cruise and the work accomplished (preliminary communications and interpretations of the results obtained are abstracted on page 292 and following).

LAND MAGNETIC SURVEY[1]

COOPERATIVE WORK

Until the end of Cruise VII of the *Carnegie* on November 29, the effective prosecution of the work at sea required the full attention of the personnel available for survey work, so that land-survey operations were held in abeyance. The urgent need of placing the records obtained on that cruise in form for final publication has required concentration upon that work for the remainder of the year. Unusual circumstances interrupted the program of the Department of Physics of the University of Cape Town, so that no field-work was undertaken during June and July and only one short expedition was made during the longer vacation in December and January. Climatic conditions during the period of the longer vacation were considered unsuitable for work in the more northerly states, Transvaal, Rhodesia, and parts of Mozambique. To allow time to complete the program in the more distant places during the favorable season from May to July, the University authorities granted a furlough of an additional month to E. N. Grindley, who has been making the observations. To provide assistance and to train an additional observer, a graduate student in the Department of Physics will accompany Grindley during a part of the trip.

The preliminary arrangements referred to in last year's annual report (p. 231) for cooperation with Director A. Walter of the British East Africa Meteorological Service have been completed, and a magnetometer with earth-inductor attachment and accessory equipment has been loaned by the Department. This instrument will be used in making observations in the eastern colonies of Africa, where observations were made by J. C. Beattie and J. T. Morrison for the Department in 1909 and a few stations were reoccupied by Observer F. C. Brown in 1921. It is proposed to establish other magnetic stations at places selected for meteorological stations and to mark them with permanent piers for periodical reoccupation.

Preliminary correspondence has been conducted with Dr. C. T. Kwei of Shanghai College, China, with whom it is expected a cooperative arrangement will be made as soon as political conditions are such as to make it expedient to travel in the interior provinces.

Magnetic observations were made fortnightly by F. T. Davies, physicist of the Byrd Antarctic Expedition, at the base-station at Little America from May 1, 1929, to February 7, 1930. No observations were possible on any of the expeditions away from the base. Instruction of observers and instrumental equipment for this work were supplied (see annual report for 1928–29, pp. 230–231 and 234) by the Department, as well as the instruments for photographic registration at the temporary observatory.

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[1] From the report of the chief of section, H. W. Fisk.

Government-Astronomer G. F. Dodwell at the Observatory, Adelaide, South Australia, with whom the Department has cooperated for some years by the loan of instruments for observations in South Australia, has made some special observations and investigations of two regions of great magnetic disturbance—near Kadina and on the west coast of Spencer's Gulf—in connection with the application of magnetic methods to the study of geological substructures.

FIELD-OPERATIONS

The following summaries indicate the scope of work on land completed during the year:

Africa—On account of the meeting of the British Association at Cape Town in July 1929, E. N. Grindley of the Department of Physics, University of Cape Town, was not able to carry out field-work during that period of vacation from University duties, as during the previous year. Illness of Professor A. Ogg, head of the Department, made it impossible to undertake an extended trip during the subsequent vacation from December to February. A short trip to a few nearer stations was possible, however, and repeat-observations were made at four stations, namely, Buffel's Bay, Eendekuil, Van Rhyn's Dorp, and Wolseley (formerly Ceres Road). Grindley left Cape Town about the first of June for the purpose of reoccupying stations in Transvaal and Rhodesia. He reoccupied by June 11, 1930, stations at Matjesfontein, Potgietersrust, Pretoria, and Machadodorp, all being repeat-localities where observations had been made during the South African survey of 1903. By arrangement through the External Affairs Department of South Africa and the courtesy of the authorities of Portuguese East Africa, permission was secured for working in that territory, and he accordingly arrived at Lorenco Marques June 12, expecting to proceed from there to Beira. His return has been planned by way of Salisbury, Bulawayo and Victoria Falls, Mafeking, and Orange River. Because of the indication that the secular rate of change in declination is materially different from that represented by the mean change over the past decade, he will reoccupy a few stations included in his expedition of 1928.

Australia—Work in Australia was limited to that at the Observatory at Watheroo and some cooperative field-studies on magnetic anomalies near Kadina and on the west coast of Spencer's Gulf in South Australia by Government-Astronomer G. F. Dodwell, using a Department magnetometer and dip-circle appurtenances.

North America—During the stay of the *Carnegie* at San Francisco, August and September 1929, observations were made at Goat Island simultaneously with those aboard during swinging of the ship in the Bay and later at Fort Scott. The latter were to compare the ship's magnetometers and inductors 12 and 24 with magnetometer-inductor 25 which had been taken by Fleming for the purpose. At Washington standardization observations were carried out as required at the Standardizing Magnetic Observatory. Among the instruments standardized was the earth inductor loaned to the Royal Alfred Observatory at Mauritius, recently completely overhauled in the Department's instrument-shop.

South America—Observations were confined to those required to maintain the standards and to control the base-lines and scale-values of the magnetograms at the Huancayo Observatory.

Antarctic Regions—As above stated, a nine-months' series of magnetograms of the three elements was obtained at the base-station of the Byrd Antarctic Expedition together with the necessary fortnightly absolute control-observations. It was not found possible to do any atmospheric-electric work, but a splendid auroral log was maintained during the period of visible display.

REDUCTIONS AND DISCUSSIONS

The general subject of magnetic secular-variation has received much attention during the year. A preliminary presentation of the available data for the epoch 1925 or as near that date as possible was made in the form of charts of lines of equal annual change (isoporic charts) of declination, inclination, total intensity, horizontal intensity, and vertical intensity. The accompanying discussion of these data has shown that certain regions are characterized by abnormally large rates of change, and that in the immediate vicinity of such regions there is a comparatively rapid change in these rates from year to year. As such areas often extend over the oceans, where land observations are impossible, it is necessary to rely upon the less precise observations made at sea. The *Carnegie* results, while quite satisfactory for determining the changes of the first order, or the annual rates, can only be used for obtaining the changes of the second order, or accelerations in the annual rates, by combining them in comparatively large groups and subjecting them to a careful analysis. The problem of finding a satisfactory method of treatment has received much attention (see p. 298).

In revising his *Directions for Magnetic Measurements*, Daniel L. Hazard, Assistant Chief of the Division of Terrestrial Magnetism and Seismology of the United States Coast and Geodetic Survey, desired to make the third edition useful to observers in all parts of the Earth and so requested the assistance of Fisk in making the necessary changes. Considerable attention was given to the preparation of suggestions based on the world-wide experience of the observers of the Department. The incorporation of these into the revised text has enhanced the value of this very useful manual by adapting it to the needs of observers in countries other than the United States. Detailed instructions for the use of the earth inductor and galvanometer of the C. I. W. type were prepared by H. E. McComb of the Coast and Geodetic Survey in consultation with Fisk. Fisk prepared a table of values of the secular variation of the magnetic elements for intersections of each 20° of latitude and longitude from 60° north latitude to 60° south latitude; this was prepared originally, at the request of the Secretary of the Smithsonian Institution, for a new edition of the Smithsonian Physical Tables.

OBSERVATORY-WORK[1]

The successful operation of the Department's magnetic and electric observatories and of its cooperative observatory-work is shown by the following brief summaries:

Watheroo Magnetic Observatory, Western Australia—The Watheroo Magnetic Observatory is situated in latitude 30° 19′.1 south and longitude 115° 12′.6 east of Greenwich, at an elevation of 800 feet above sea-level.

The magnetograph was operated continuously and there were no major, and few minor, interruptions to the continuity of the record, the total loss throughout the year amounting to only a few hours. The necessary control-observations were carried out regularly and computations of the base-lines and scale-values forwarded monthly to Washington. The reduction and tabulation of the hourly values of all three elements were kept current. The preliminary mean values of the magnetic elements as deduced from the magnetograms for all days of the year 1929 are: Declination, 4° 12′.1 west; horizontal intensity, 0.24645 C.G.S. unit; vertical intensity, −0.51115 C.G.S. unit; and inclination, 64° 15′.5 south. The preliminary values of the annual changes in the magnetic elements for the period 1928.5 to 1929.5 are 2′.9 east in declination, 11 gammas decreasing in horizontal intensity, 45 gammas increasing numerically in vertical intensity, and 1′.7 south in inclination.

The differences in potential between one common and four other electrodes of the earth-current measuring-system were also continuously recorded, though with a somewhat greater loss of record than was the case with the magnetograph, owing to the greater liability of instrumental breakdown and line-trouble. However, reliable mean values have been obtainable for all months on all four lines. Other than the necessary repairs and overhauls, the Leeds and Northrup multiple-point recorder used on this installation has remained unchanged and has given self-consistent records from all electrodes. The electrode 9.86 km. east, which previously gave trouble during the dry season by developing a contact-potential which was beyond the range of the recorder, has this year remained well within the recording limits of the instrument; therefore, there has been no occasion to make use of the auxiliary electrode near this point which was laid down during the previous report-year.

The recorder of air-potentials has functioned excellently throughout. The routine of automatic and manual leak-tests, which was standardized during the last report-year, has been maintained and there appears to be no doubt regarding the adequacy of the insulation of the collector-system. The only occasions upon which there has been a leak sufficiently large to cause an appreciable lowering of the recorded potentials (that is, over one per cent per minute) were during the spider-season (September to December) when fine webs from spiders floating through the air became attached to the collector-rod which projects from the side of the building. These occurrences were comparatively rare and did not prevent the taking of monthly means. No monthly means were obtained for January, February, or March owing to the prevalence of smoke from bush-fires. Standardisation-observations were carried out approximately monthly for determination of the "reduction-factor." The mean of the series taken during the year is 1.12, as before. The preliminary mean value of the potential gradient for the year 1929 is 87 volts per meter; previous values in volts per meter were 87 in 1924, 84 in 1925, 77 in 1926, 79 in 1927, and 82 in 1928. Special observations, involving the use of auxiliary recording-apparatus at several field-stations in the vicinity of the present recorder, are in progress in an endeavor to determine whether the low values of potential gradient consistently recorded during the night hours of the rainy season between May and August are normal or not.

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[1] From the reports of the observers-in-charge.

The apparatus for the simultaneous recording of positive and negative air-conductivity has been maintained in running condition, although there was some loss of record on several occasions. The original air-resistance cells (Nos. 3 and 4) were replaced October 1929 by new ones (Nos. 9 and 10), resulting in considerable improvement in the linearity and constancy of the scale-values for the two sides of the apparatus. During the progress of the experiments incidental to replacing the ionium-cells, the significant fact was discovered that linearity was obtainable with either of the air-resistance cells only when used with the positive conductivity-apparatus. The departure from linearity was of the order of ten per cent when either cell was used with the negative conductivity-apparatus. Subsequent to the replacement of the ionium-cells there was some variation in the scale-value of the positive apparatus owing to the instability of the quadrant-electrometer; this trouble was finally eliminated by providing a new type of supporting tripod and readjusting the electrometer. The preliminary mean value for the positive air-conductivity for the year 1929 is 1.81×10^{-4} E.S.U. and for the negative air-conductivity 1.52×10^{-4} E.S.U., which agree closely with those for 1928.

Wood continued his research work on atmospherics, with a view to completing a postgraduate-degree course in the Department of Physics of the University of Western Australia. He has maintained in continuous operation the directional recorder of atmospherics which was loaned by the Australian Radio Research Board of the Council for Scientific and Industrial Research (see annual report for 1928–29, p. 236). In January 1930, Wood conferred with a member of the Radio Research Board, and, as a result, the Board has undertaken to convert the recorder into one of a more modern type as recently developed at the Radio Research Station, Slough, England. It is anticipated that a similar recorder will soon be in operation at the Mount Stromlo Solar Observatory, Canberra, and that the two observatories will work in conjunction with the Radio Research Board on the problem of atmospherics. Wood has extended his investigation in this direction by erecting a unidirectional receiving antenna for the purpose of standardizing the atmospherics-recorder at regular periods and at the same time to resolve the bidirectional ambiguity which is present in the recorder.

Builder had a short-wave radio equipment in operation under the Observatory call sign VK6MO until the end of February 1930, when failure of high-voltage batteries for the transmitter necessitated closing the station temporarily. Transmitter-outputs up to 15 watts were used and daily testing-schedules were maintained with other Australian stations. In response to a request from the Southern Cross Inquiry Board, low-power transmission-tests were carried out.

The Wireless Institute of Australia suggested that the Observatory could maintain communication with Washington by amateur relays and obtained special permission for Australian stations to handle the messages for the Department. The arrangement was not satisfactory as few Australian stations had regular American schedules. In November 1929 W1MK, the headquarters of the American Radio Relay League, arranged a schedule route via KA1HR (Philippine Islands), W6TM (California), and W1MK. This route was maintained until the station closed at the end of February 1930. Regular biweekly schedules were kept with KA1HR and for the greater part of the time messages passed rapidly. Communication was also established with the *Carnegie* via KA1HR and W6TM. In December 1929 a special grant was made by the Institution at Washington to enable the Department to equip the Observatory with short-wave transmitting and receiving apparatus. A small 15-watt set operating on a rotary-transformer (32 to 600 volts) has been built as an emergency transmitter. A 250-watt crystal-controlled set is under construction and will soon be in use, with high-tension supply from a 2,000-volt generator. The receiver has also been built, and on May 10, 1930, VK6MO was again working, using the small transmitter, and a new schedule-route was put into operation via VK5HG (South Australia) and W9CKQ (Fort Madison, Iowa). These stations keep daily test-schedules and messages go forward without delay. Magnetic character-numbers are transmitted to the Department weekly as well as detailed descriptions of all magnetic storms. With the completion of the equipment planned, it is hoped that regular communication direct to the United States will be possible, thus permitting rapid transmission of data relating to magnetic and electrical conditions at Watheroo and assisting materially the Department's cooperation in the plans for daily broadcasting of cosmic phenomena as planned by the International Union of Scientific Radiotelegraphy.

Johnston represented the Institution at the Conference of Physicists, Astronomers, and Mathematicians held at Melbourne in August 1929, and presented three papers (abstracted on pp. 295 and 322) prepared by members of the Watheroo staff entitled *Directional recording of atmospherics at Watheroo* by F. W. Wood, *Effect of condensation-nuclei on atmospheric-electric elements* by G. Builder, and *Preliminary note on atmospheric potentials recorded with ionium-collectors* by G. Builder. Members of the staff have from time to time prepared memoranda regarding details of operation and adjustment of instrumental equipment. Among these is one by Builder on *Some notes on potential-gradient records at Watheroo,* having particular reference to investigations of insulation-leaks in the potential-gradient recorder as a source of uncertainty in the records.

The necessary maintenance and repair work have been carried out, as well as the regular meteorological and other observations, computations, and tabulations. A central heating-system was installed in the observers' quarters. The building used for auxiliary quarters was improved and an additional room was provided for the storage-batteries. A half-mile of double-ribbon road was constructed across the least passable part of the sand-plain. The scrub-clearing was extended to give added protection against bush-fires.

The Observatory was favored with visits from a few people during the year, including Professor A. D. Ross of the University of Western Australia, who maintains his keen interest and helpfulness in the functioning of the Observatory.

Johnston continued in charge until November 22, 1929, when he was succeeded by Parkinson, who arrived at Watheroo on April 19, 1930. During this long interval, occasioned by the *Carnegie* disaster, Observer Wood very ably carried on the direction of the Observatory affairs as Acting Observer-in-Charge. Builder, observer, and Caswell, assistant, served throughout the report-year, rendering efficient aid. During term-vacations, temporary scientific assistance was supplied by students of the Department of Physics from the University of Western Australia, including S. E. Colstead, H. D. Poole, and G. P. Falls.

It is a pleasure to place on record our acknowledgments to the Federal Minister of Customs for his assistance in allowing entry, free of duty, of equipment and supplies and also to the Chief Inspector, Wireless Branch, Postmaster General's Department, for his keen interest in the Observatory's radio research-program and his promise of all facilities possible.

Huancayo Magnetic Observatory, Peru—The Huancayo Magnetic Observatory is situated in latitude 12° 02′.7 south and longitude 75° 20′.4 west in the valley of the Montaro River at an altitude of 11,000 feet above sea-level and about nine miles from the town of Huancayo. The valley is surrounded by mountains which are from 14,000 to 18,000 feet in height.

The magnetograph, atmospheric potential-gradient recorder, atmospheric conductivity-recorder, and the earth-current recorder have been kept operating during the year with a minimum of accidental failure. Monthly scale-value determinations have been made for the magnetograph and weekly absolute magnetic observations for the evaluation of the magnetograph base-lines Weekly scale-value deflections have also been made for the atmospheric-electric instruments and biweekly calibrations of the earth-current recorder. Eleven monthly reduction-factor determinations for the potential-gradient recorder have been made during the year—weather-conditions in February did not permit observations.

Time-signals have been received regularly, and the chronometers and the electric clock have been compared for correction and rate. Continuous meteorological records have been kept of the temperature, barometric pressure, humidity, direction and velocity of the wind, rainfall, hours of sunshine, and amount of cloudiness.

Rooney, during eight months at the Observatory beginning in May 1929, made a careful survey of the earth-resistivity conditions in the neighborhood of the two Observatory earth-current systems I and III. He was assisted in this work by members of the Observatory staff as occasion demanded, particularly by T. Astete, who helped in much of the field-work. (The results of his earth-resistivity survey are abstracted on p. 312.) Rooney also gave invaluable assistance to the Observatory staff in reducing the instrumental data, which at the beginning of the report-year averaged six months or more in arrears. This work was brought up to date early in December.

The installation of concrete poles for carrying the lines from the electrodes of the two earth-current systems (see annual report for 1928–29, p. 238) was completed during the latter part of the year. There was some loss of record through the breakage of the old eucalyptus poles previous to their replacement. There was also the usual trouble in the operation of the recorder caused by lightning-discharges which at times damaged the instrument and occasioned some loss of record. The east-west electrode-separation on system III was shortened by the planting of a new electrode (III*M*) within the Observatory grounds. The records obtained from this shortened distance are so much superior to those previously secured from the longer distance that a new plot has been purchased which will give a shorter north-south electrode-separation; this new electrode will be marked III*C* and will be installed and put in operation some time in July 1930.

The installation of the hydraulic ram (see annual report for 1928–29, p. 238) on the Chupaca River for pumping water to the Observatory was completed November 14, 1929. With this new water-supply system, the

Observatory has been freed from its previous condition of continuous water-shortage during the long dry-season, about 900 gallons of water being delivered daily—the excess over ordinary Observatory requirements is used for irrigation.

Buildings, fences, and grounds have been kept in good condition and improvements made. The Delco-Light electric system and the Graham Brothers truck have been kept in good operating condition and have given satisfactory service.

P. G. Ledig has remained in charge of the Observatory during the year. He will report at Washington for a conference regarding the Observatory's program in July and is to return in October 1930. During this interim, S. E. Forbush, who returned in May after ten months of duty on the *Carnegie,* will be acting observer-in-charge. V. J. Eaton returned to the United States in December 1929. R. E. Gebhardt continued as observer throughout the year. M. T. Quintana has continued as observatory aid, and T. Astete has been general and office assistant during the greater part of the year.

No manuscripts or publications, other than reports of magnetic conditions recorded and memoranda on details of the Observatory's operations, were prepared at the Observatory. Experimental investigatory work had to be limited to that concerned with the routine collection and reduction of instrumental data, which, with the completion of the construction projects previously noted, occupied fully the available time of the staff.

Visitors at the Observatory have been frequent, largely from Huancayo and the surrounding country, but also from Lima and other parts of Peru. The Observatory has been able to give assistance to several agencies by supplying meteorological information, particularly to the Sociedad Geografica de Lima, which was given a meteorological summary covering the entire period since the beginning of operations at the Observatory.

The staff has continued to take part in local affairs and has in return enjoyed the cordial good-will, evidenced by friendly relations and assistance, from local residents and merchants who have been, as heretofore, factors in the success attending the work. The Observatory again acknowledges gratefully the assistance given by the United States Embassy at Lima in obtaining free-entry for Observatory materials and supplies and the helpful, interested attitude of the government officials of Peru.

Washington, United States—The recording of potential gradient and conductivity was continued in the observatory on the deck of the main laboratory at Washington throughout the report-year. Sherman, who has had immediate charge of this observatory, reports that the records for potential gradient were 84 per cent complete and those for conductivity 87 per cent complete. The potential-gradient records for the calendar year on 107 days were free from negative potentials, mean potential from these being 149 volts. The reduction-factor as determined on seven different occasions by Wait, Sherman, and Gebhardt from 66 twenty-minute sets of readings is 1.27, as compared with the value of 1.17 obtained during the previous year. It thus appears that the tendency towards an increasing reduction-factor continues. Special tests of the insulation of the potential-gradient recorder were made in August 1929 by using a screen-shield over the collector-arm. With this shield earthed, the decay rate was about one per cent per minute. With the screen at the same potential as the collector, no change could be detected in a seven-minute interval. Evaluation of the records has been kept current by Sherman and considerable progress made in the preparation of these data for publication. Final reductions of potential gradient for the five-year period 1924–1928 have been completed (see p. 305).

A series of measurements of condensation-nuclei, extending throughout the 24 hours of March 27 and 28, 1930, was made by Wait, Torreson, and Sherman (see p. 320).

The control and investigations of magnetic instruments for use in the field and at observatories was continued in the non-magnetic Standardizing Magnetic Observatory at Washington. Some use of this Observatory was made also by the United States Coast and Geodetic Survey in cooperative studies, and in turn the Department had the privilege of using, when desired, that Survey's magnetic observatory at Cheltenham.

Among the instruments tested, standardized, and compared with the Department's standard-instruments, namely, magnetometer 3 and earth inductor 48, were: Magnetometer-inductor 25 after its return from San Francisco, where it was used in making comparisons with the *Carnegie* instruments; combined magnetometer and inductor 18 prepared and forwarded for the cooperative survey in the British colonies of Africa with the British East Africa Meteorological Service of the Conference of East African Governors; earth inductors 5 and 4, the former the standard instrument of the Huancayo Magnetic Observatory and the latter of the Royal Alfred Observatory at Mauritius, both of which instruments had been sent to Washington for overhauling and repairing and which were returned to the observatories.

COOPERATIVE OBSERVATORY-WORK

Apia Observatory, Western Samoa—Cooperation with the Apia Observatory (latitude 13° 48′ south, longitude 171° 46′ west) at Apia, Western Samoa, was continued. Although the assistance has been chiefly, as in previous years, in maintaining the atmospheric-electric program, the Observatory has received guidance and advice in other activities. The work of the Observatory consists mainly of obtaining precise measurements in meteorology, terrestrial magnetism and electricity, and seismology. Owing to the isolated location on a small island not far from the center of the Pacific Ocean, the records reveal slight cosmic changes which frequently can not be detected at continental observing-stations.

The Observatory has been controlled since July 1928 by the Department of Scientific and Industrial Research of the Dominion of New Zealand. It has received yearly subsidies both from the British Admiralty and the Department of Terrestrial Magnetism. The staff consists of the director, A. Thomson, the assistant director, C. J. Westland, scientific assistant, K. C. Sanderson, and four Samoan clerks and aids. From January 9, 1929, to March 6, 1930, during the absence of the director, Assistant Director Westland was in charge of operations at the Observatory.

Hourly values of the magnetic declination and horizontal intensity were obtained without interruption throughout the year. The mean values from observations on all days for 1929 were: Declination, 10° 33′.5 east (whole year); horizontal intensity, 0.35029 C.G.S. unit (whole year); vertical intensity, −0.20418 C.G.S. unit (June to December only). These show since 1928 an increase of 1′.4 in east declination, a decrease of 16 gammas in horizontal intensity, and an indicated small change in vertical intensity as the mean value of −0.20408 C.G.S. unit for 1928 depends on five months only. The staff of the yacht *Carnegie* repaired the Schulze earth-inductor in April 1929 and practically continuous records of the vertical magnetic force were subsequently obtained. The *Carnegie* visited Apia from April 6 to 20 and made a thorough intercomparison of the Observatory's absolute magnetic instruments. Preliminary computations indicate little change has taken place since the last intercomparison by that vessel on her visit in 1921. The *Carnegie* was destroyed by explosion and fire as she lay at anchor in the harbor on November 29, 1929, on the second day of her last visit to Apia. During the four months following this disaster, while Parkinson was in charge of salvaging operations on the wreck he gave assistance and counsel at the Observatory in instrumental and other matters, particularly in atmospheric-electric work.

Days were classified according as the daily magnetic variations were normal, slightly disturbed, or considerably disturbed. The individual daily character-values were supplied quarterly to the Secretariat of the Comité International at De Bilt Observatory, Holland. Magnetic storms occurred February 26–28, March 11–11, May 23, July 15, and September 22, 1929. Although the number of disturbed days was unusually high, the disturbances were not intense, but continued for a longer time than usual. The number of sunspots observed in 1929 was above the average which is closely related to the unusually disturbed magnetic state of the Earth observed.

In July 1929, Dr. W. S. Adams, director of Mount Wilson Observatory, gave on indefinite loan a spectrohelioscope to the Apia Observatory. Owing to the reduced staff during the remainder of the year, this instrument has not been set up.

Atmospheric-electric potential records were obtained throughout the year at both the land-station in the Observatory grounds and at the lagoon-station erected in the shallow off-shore water inside the coral reef. The lagoon-station records were practically complete and the difficulties of insulation have been largely overcome. The physical conditions of sea and reef in the vicinity of the lagoon observing-hut are unchanging, so that records from this station should have a unique use in providing data for determination of secular change. The Department obtained essential replacement parts of the apparatus from Austria for carrying on these observations. Reduction-factor of electrometer-readings at both stations to a plane surface were obtained on two occasions on the nearby coral reef when laid bare at low tide. Although the results from the two stations closely resemble each other, the daily maxima and minima are more pronounced in the records at the lagoon-station than at the station in the Observatory grounds.

The meteorological and seismological programs have been continued as heretofore. The mean temperature for the year was 79°.64 Fahrenheit and the extreme lowest temperature was 68°.2 and 4 a.m., August 14. The monthly rainfall varied from 24.22 inches in January to 2.29 inches in September, with a relative humidity during these months of 86 per cent and 74 per cent, respectively. The observation of winds at high altitudes has been continued. Sixty pilot-balloons were released, of which thirteen were followed to heights of 10 kilometers or more. These long flights invariably disclosed the presence of strong westerly winds at great heights moving contrary to the southeast trades blowing at levels below 10,000 feet. The advent of airship travel makes it most desirable to secure further data of upper winds not limited as hitherto to days with unclouded skies.

Other Observatory activities have included the measurement on a few days of solar radiation, the supervision of the South Pacific Weather Reporting Service, and the maintaining of a time-service for rating chronometers of local shipping.

The manuscript for the report giving the results obtained during 1927 was completed and the type has been set up and proof-read. Final printing and distribution awaits some slight additional corrections after the return of Thomson to New Zealand on completion of special magnetic and electric observational program he is to carry out as a member of the solar-eclipse expedition to Niuafou Island in October 1930. Preparations and plans for the latter work were made during the report-year by Thomson in cooperation with Dr. C. E. Adams, leader of the New Zealand party to which Thomson will be attached; the Department cooperated in this by making ready a portable conductivity-apparatus which was forwarded in June through the courtesy of the Superintendent of the United States Naval Observatory with equipment being shipped for the Naval Expedition.

Tucson, United States—The cooperative arrangements with the United States Coast and Geodetic Survey for atmospheric-electric work at the Tucson Magnetic Observatory (latitude 32° 14'.8 north, longitude 110° 50'.1 west, elevation above sea-level 2525 feet), referred to on page 242 of the annual report for 1928–29, were completed. Continuous photographic recording of atmospheric potential-gradient and of positive and negative conductivity began for the potential gradient in September and for the conductivity in October. Observer-in-Charge Ludy at Tucson has attended to the routine work necessary in connection with these registrations. Observer J. Hershberger of the staff of the Coast and Geodetic Survey is to be assigned early in July 1930 as assistant to Ludy In anticipation of this assignment, Hershberger spent several months during the latter part of the report-year at the Department's laboratory in Washington, familiarizing himself with atmospheric-electric instruments, with the methods of their adjustment and use, and with preparation and discussion of such data for publication.

REDUCTIONS OF OBSERVATORY RECORDS

Magnetic records—Final reductions of the magnetograms of the Watheroo Magnetic Observatory through the calendar year 1928 were completed by Edmonds and Miss Balsam, and are ready for direct reproduction in Volume VII of the Department's *Researches*. The reductions and tabulations for the calendar year 1929 and the year 1930 are already in progress.

Green continued the final office compilations of the results recorded at the Huancayo Magnetic Observatory, and Miss Balsam has already prepared and practically completed a large part of the tabulations of declination-results from the beginning of the work in July 1922.

Wallis completed the discussions and investigations of the magnetograph data of the two MacMillan expeditions of 1921 to 1922 and of 1923 to 1924. Some of these data were utilized by Wallis in the discussion of world-wide characteristics of magnetic storms (for abstracts of this work see p. 321).

Electric records—Analyses of the atmospheric-electric records for potential gradient and conductivity at the Watheroo and Huancayo observatories and at the Tucson Observatory are under way. Details relating to these discussions are given on pages 261–262.

INSTRUMENT-SHOP[1]

As in previous years, the work done by the small personnel of the instrument-shop in the design and construction of permanent instruments and equipment and of experimental apparatus has been noteworthy. The time of the shop-personnel for the year totals about 10,000 man-hours which were devoted to improvement, repair and new construction of special and standard equipment and apparatus, and to miscellaneous items.

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[1] From the report of electrical engineer C. Huff, in charge of shop.

The glass-blowing lathe—of such distinct use in the progress of the high-voltage investigations—was completed and installed. A new type of water-dropper for securing high potentials for use aboard the *Carnegie,* and a new type of potential-gradient collector-rod for observatory-use were designed and constructed. Time-marking devices for observatory earth-current recorders were made. An experimental device (ordinate-integrator, see p. 307) for measuring magnetic activity was designed and constructed. Other new work and improvements included installation of ventilating-apparatus in the enameling-room, of a blower-system for the main shop, for the glass-shop, and for the Experiment Building.

Magnetometer-inductors 26, 27, and 28, theodolite 4, earth inductors 4 and 5 and galvanometer for the former, were generally overhauled and refinished. Considerable time was taken in the maintenance of instruments, equipment, shop-machinery, and buildings.

Experimental items occupied a large amount of the available time, including particularly development of equipment for the high-voltage and the Kennelly-Heaviside-layer apparatus, of apparatus for experimental work on the *Carnegie,* of a dynamic-deviation apparatus to be used at the Laboratory, and the initiation and design of a short-wave radio transmitter. A Wilson-Blackett cloud-chamber and its accessories, and a large electromagnet, both for use in the high-voltage and conducting-layer investigations, have been designed and partially constructed.

MISCELLANEOUS ACTIVITIES

International and national unions and commissions—Bauer continued as President of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union, and as a member of the Committee on Solar Physics of the American Section of the International Astronomical Union and of the International Research Council's Committee for the Study of Solar and Terrestrial Relationships.

Fleming and Harradon were appointed delegates from the United States to represent the American Geophysical Union at the Stockholm Assembly of the International Geodetic and Geophysical Union to be held in August 1930, and Kennelly and Fleming have been designated representatives of the Carnegie Institution of Washington at this Assembly. Reports and communications for the Department to the International Sections of Terrestrial Magnetism and Electricity and of Oceanography at this Assembly were prepared by members of the staff and issued June 30 as a planographed volume of 111 pages for distribution at Stockholm.

Fleming was appointed a member of the International Commission on Terrestrial Magnetism and Atmospheric Electricity of the International Meteorological Committee, and also a member of its Commission on the International Polar Year 1932–33.

Peters continued as a member of the American Committee of the International Union of Scientific Radiotelegraphy on Cooperation. Fleming served again on the International Committee on Oceanography of the Pacific. Various members of the staff supplied information to the National Research Council as requested.

As heretofore, the staff took active part in the work of the American Geophysical Union. Fleming, Peters, Gish, and Fisk served on the Executive Committee of the Union, Fleming continuing as the General Secretary of the Union and Fisk and Gish being Secretaries of the Sections of Terrestrial Magnetism and Electricity and of Meteorology, respectively. The Department's researches were well represented during the eleventh annual meetings of the Union and its sections by contributions to the three sections, namely: Terrestrial Magnetism and Electricity by Sverdrup, Gish, Peters, Soule, and Fisk; Oceanography by Fleming, Sverdrup, Soule, and Ennis; and Geodesy by Forbush and Torreson. (Brief accounts of the papers will be found in this report under "Abstracts of Publications and Investigations.") Fleming edited the numerous papers presented at the tenth and eleventh annual meetings for publication and, with Capello, prepared them for planographing; the 314-page volume of these transactions was distributed in June.

Fleming, in the illness of Bauer, was the responsible editor of the "Journal of Terrestrial Magnetism and Atmospheric Electricity" published by the Johns Hopkins Press; this quarterly international journal, founded by Bauer, is now in its thirty-fifth volume. During the past year the interest in the fields covered by the Journal has so increased both in America and in Europe that it has been necessary to enlarge the size of the printed page and to increase the total number of pages in the annual volume by about fifty per cent over the average volumes preceding 1927 to accommodate the worth-while articles and notes offered for publication. Fleming was named a collaborator of the editorial board of Gerlands "Beiträge zur Geophysik."

Conferences, colloquia, lectures—Two of the Institution's spring series of lectures were from the Department, namely, "Some aspects of oceanography" by Sverdrup, April 8, and "Natural electric currents in the Earth's crust" by Gish, April 15. A series of papers describing the various features of the *Carnegie's* work was presented at the Philosophical Society of Washington, April 12, including terrestrial magnetism by Fleming, atmospheric electricity by Gish, biology and chemistry by Graham, meteorology by Paul, and oceanography by Soule. Other papers communicated to this Society were: "A comparison of magnetic disturbance at different stations" by Wallis on February 1, and "Earth-resistivity survey at Huancayo, Peru, and relation of resistivity to earth-current potentials" by Rooney on March 15.

Of especial interest this year were the weekly atmospheric-electric seminar meetings held at the Laboratory on 16 evenings during November to April under the leadership of Gish. The papers presented and discussed at these meetings were: Mobility of small ions, by Wait; The constants of atmospheric electricity, by Gish; Electricity of thunderstorms, by Torreson; Lightning characteristics deduced from observations made by radio methods, by Hafstad; Review of the work of P. E. Shaw on tribo-electricity, by Sherman; Experimental and theoretical work of Elster and Geitel, Lenard, and others on the mechanism by which an electric charge is developed on rain, by Gish; Character of ions produced by sprays, drifting snow, etc., by Forbush and Gish; Theory of mechanism of lightning-discharges, by Dorsey (by invitation); Review of recent papers on factors affecting the equilibrium-number of small ions in the atmosphere, by Wait; Nature of Aitken nuclei, by Wait; Thunder-cloud problems, by Torreson; Sources of ionization of the atmosphere, by Rooney; Studies of penetrating radiation, by means of the Geiger-Müller counter, by Tuve; Some puzzling aspects of atmospheric-electric data obtained on the *Carnegie,* by Wait; Theoretical examination of the performance of some instruments used in atmospheric-electric measurements, by Gish.

Because of the demands on the office personnel following the disaster to the *Carnegie,* the series of biweekly staff meetings on theoretical aspects of terrestrial magnetism and electricity was somewhat curtailed during the past winter. During October to December, however, there were several meetings to consider and discuss the subjects to be presented for the agenda of the International Section of Terrestrial Magnetism and Electricity at the Stockholm meeting, one of these being a joint conference with the members of the American Section at which final decision was reached regarding the agenda items to be proposed. At another meeting Hulburt of the Naval Research Laboratory spoke on the ionization of the upper atmosphere. As in the past, these meetings were attended by members of staff of the United States Coast and Geodetic Survey and of the Naval Research Laboratory as well as of the Department, and there was always vigorous, helpful, and constructive discussion. The weekly evening colloquium on atomic physics was continued throughout the year under the leadership of Tuve as regards the Department participation.

Exhibits—As one of three celebrations of the Institution to commemorate the twenty-fifth anniversary of the inauguration of its research activities, an exhibition was prepared for and held on board the *Carnegie* in San Francisco Harbor, August 26, 27, and 28. Naturally the exhibit feature was the vessel and her equipment. A twenty-four-page, illustrated pamphlet was distributed during the three days, having been prepared in Washington by Dr. Bunker, Editor of the Institution, from memoranda largely supplied by the Department members.

The contribution of the Department to the Institution's annual exhibit in December related to (*a*) progress of Cruise VII of the *Carnegie* and (*b*) application of high voltages to vacuum-tubes for the production of penetrating-radiations. Under (*a*) there were a number of separate items including a globe showing the tracks of cruises I to VII of the *Carnegie,* a chart showing utilization of magnetic data obtained, apparatus demonstrating errors of compass caused by ship's rolling, moving graphs showing daily variation at sea in electric pressure of the atmosphere, graphs showing results on physical oceanography, and samples and graphs showing marine biological and chemical results. The exhibits under (*b*) were a sectional high-voltage tube and an electron tube-counter, the latter as constructed by and used at the Department for studying radiations from high-voltage tubes and for studies of penetrating-radiations from space.

Fleming and Torreson served on the Institution's committee on exhibits, and the former was also a member of its committees on the twenty-fifth anniversary commemoration and on lectures. Fleming has been appointed a member of the "advisory committee for an investigation of high altitudes in the atmosphere"—a committee formed by President Atwood of Clark University to forward scientific investigations of the upper atmosphere in connection with the rocket-work of Professor R. H. Goddard of the faculty of that University.

Library—The special field covered by the library of the Department embraces works dealing with terrestrial magnetism and electricity, and every effort has been made to acquire all publications on these subjects. However, as they are intimately related to the general science of physics, and more particularly to the all-embracing domains of terrestrial and cosmical physics including oceanography, it is also necessary to procure outstanding current works along these lines.

The accessions during the report-year have been 849, making the total number of reprints and volumes now 17,464. This number of new acquisitions, however, is in no sense an indication of the number of titles added to the card-catalog, since our practice is to card, classify, and incorporate in the card-index all important articles dealing with atmospheric electricity, terrestrial magnetism, polar lights, earth-currents, and other geophysical and cosmical subjects, which have a bearing on the present or projected activities of the Department and which appear in current scientific journals of which over 75 are regularly received and kept on file for reference. The card-catalog and accumulated publications are much-used and almost indispensable tools for our experimental and investigational work.

A considerable loss of books was suffered through the destruction of the *Carnegie*. In most cases the works destroyed could be replaced, but several rare series of scientific publications of oceanographic expeditions—practically indispensable for the successful execution of the research program of the vessel—can not be replaced.

Throughout the year, attention was given the publication of the Journal of Terrestrial Magnetism and Atmospheric Electricity, particularly in editing foreign manuscripts, preparing notes, and writing reviews. Especial care was taken in preparing the bibliography published in each number, thus distributing widely and economically a reliable index to contemporaneous literature on terrestrial and cosmical magnetism and electricity—favorable and encouraging comments received from various quarters indicate that this is a real service.

As in previous years, many articles and letters, some at the request of the Institution, have been translated from various foreign languages. Preparations have been made for Harradon to attend with Fleming the meeting of the International Geodetic and Geophysical Union at Stockholm in August.

Supplementing earlier lists, Kolar prepared a list of the publications by members of the Department for the year ended December 31, 1929. The total number of such publications then was nearly 850.

Investigators from laboratories and institutions not only in Washington but also from other parts of the country have come to take advantage of the special facilities of the library which have been placed freely at their disposal. Not alone have personal consultations been made, but inquiries for information here available have been satisfied by correspondence. The reciprocal relations with other libraries, particularly the Library of Congress, have been continued and have proved, as in previous years, of mutual help and advantage.

Publications—Abstracts of articles published, of papers presented before scientific societies, and of investigations under way (or completed but unpublished) are briefly summarized in the following section of this report.

ABSTRACTS OF PUBLICATIONS AND INVESTIGATIONS

Preliminary results of ocean magnetic observations on the *Carnegie* from Tahiti to Samoa to Guam to Japan, March to June 1929; from Japan to California to Hawaii, June to September 1929; from Hawaii to Samoa, October to November 1929. J. P. Ault. Terr. Mag., vol. 34, 249–256 (September 1929); 287–291 (December 1929); vol. 35, 17–21 (March 1930).

These articles continue and conclude the series giving the preliminary magnetic results obtained during Cruise VII of the *Carnegie*, which was so unfortunately the last cruise because of the disaster to the vessel in Apia Harbor, November 29, 1929. The tabulations show the dates, geographic positions, and observed values for the three elements, with chart-differences for the three elements determined from the latest editions of the British, German, and American charts. Notes giving details of each of the passages covered follow the tabulations of results. These notes indicate generally the work done and give some account of the conditions of weather and sea encountered and of the logs.

Address on the occasion of the second celebration of the twenty-fifth anniversary of research of the Carnegie Institution of Washington. J. P. Ault. Science, n. s., vol. 60, 247–248 (September 13, 1929).

This address summarizes the progress in the fields of terrestrial magnetism and atmospheric electricity made through accumulation of observational data and their reduction and discussion by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington since its formation April 1, 1904, giving particular emphasis to the work done in the magnetic and electric surveys on the oceans and a brief historical account of it. The development of an extensive oceanographical program during Cruise VII of the *Carnegie* and its execution are briefly reviewed.

Science aboard the *Carnegie*. J. P. Ault. Discovery, vol. 10, 329–332 (October 1929).

An unsolved mystery of the Pacific. J. P. Ault. Discovery, vol. 10, 359–361 (November 1929).

These two articles give popular accounts of the scientific activities and life aboard the *Carnegie* during the first part of her seventh cruise. The second article deals with the call at Easter Island.

Preliminary values of the annual changes of the magnetic elements in the Caribbean Sea and the Pacific Ocean, as determined from the *Carnegie* results, 1909–1929, and from the *Galilee* results, 1905–1908. J. P. Ault and H. W. Fisk. Terr. Mag., vol. 34, 292–299 (December 1929).

Annual report of the Director of the Department of Terrestrial Magnetism. Louis A. Bauer and J. A. Fleming. Carnegie Inst. Wash. Year Book No. 28, 1928–1929, 209–276 (1929).

This report covers the operations of the Department for the year July 1, 1928, to June 30, 1929. Following the general summary the details of the various lines of work are briefly given under the following sub-headings: (*a*) Investigational and experimental work including terrestrial magnetism and electricity and cosmical relations, contributions of research associates, magnetism and atomic physics, experimental work in terrestrial electricity; (*b*) field-work and reductions including developments and improvements in magnetic instruments for field and observatory, ocean-work, land magnetic survey, observatory-work, instrument-work, and buildings; (*c*) miscellaneous activities; and (*d*) abstracts of publications and investigations. It is to be noted that the abstracts under (*d*) include not only brief accounts of published investigations and articles but also investigations, experiments, and discussions under way during the year.

Report of the Secretary and Director of Central Bureau, 1924–27. Louis A. Bauer. Trans. Prague Meeting, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., September 1927. Bull. No. 7, 5–11 (June 1929).

Secretary's summary of Prague Meeting. Louis A. Bauer. Trans. Prague Meeting, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., September 1927. Bull. No. 7, 44–47 (June 1929).

Report on comparison of instruments—supplementary notes. Louis A. Bauer. Trans. Prague Meeting, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., September 1927. Bull. No. 7. 55–56 (June 1929).

Department of Terrestrial Magnetism, Carnegie Institution of Washington: Report on work done since the Madrid Assembly. Louis A. Bauer and J. A. Fleming. Trans. Prague Meeting, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., September 1927. Bull. No. 7, 150–174 (June 1929).

Comments on Agenda for the Prague Assembly, Department of Terrestrial Magnetism, Carnegie Institution of Washington. Louis A. Bauer and J. A. Fleming. Trans. Prague Meeting, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., September 1927. Bull. No. 7, 190–202 (June 1929).

These five communications are concerned with progress of the activities of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union during 1924–27 and reports made at the Prague Assembly in September 1927. The report of the Department summarizes its operations during the three report-years ending June 30, 1927, and details the work done or applying in that time on the resolutions adopted at the Prague Meeting by the Section.

Terrestrial Magnetism and Atmospheric Electricity: An international quarterly journal. Louis A. Bauer and J. A. Fleming, Editors. Vol. 34, Nos. 3 and 4, 173–338 (September and December 1929); vol. 35, Nos. 1 and 2, 1–124 (March and June 1930).

This international journal was continued into its thirty-fifth year with a greatly increased number of original articles showing greatly increased interest in its fields. In addition to leading original illustrated articles, there are sections of (*a*) letters to editor, (*b*) principal magnetic storms, (*c*) reviews and abstracts, (*d*) notes, and (*e*) list of recent publications. This journal thus serves not only to promote prompt publication of results of research but also international distribution and intercommunication of information essential to the coordination of effort in the cooperation so essential in geophysical work of many investigators.

On the possibility of nuclear disintegration by artificial sources. G. Breit. Phys. Rev., vol. 34, 817–818 (September 1, 1929).

Group-velocity and long retardations of radio-echoes. G. Breit. Proc. Inst. Radio Eng., vol. 17, 1508–1512 (September 1929).

This is a reprint in final form of the paper already abstracted on page 251 of the annual report for 1928–29.

A correction to "The propagation of Schroedinger waves in a uniform field of force." G. Breit. Phys. Rev., vol. 34, 1491 (December 1, 1929).

Separation of angles in the two-electron problem. G. Breit. Phys. Rev., vol. 35, 569–578 (March 15, 1930).

Neglecting the spin, two electrons are described in quantum mechanics by means of a wave-equation in six variables. This communication shows that well-known relations between angular-momentum operators make it possible to determine the dependence of the wave-function on three variables, thus reducing the problem from six to three dimensions.

Possible effects of nuclear spin on X-ray terms. G. Breit. Phys. Rev., vol. 35, 1447–1451 (June 15, 1930).

It is shown that magnetic moments of nucleii are likely to cause small but presumably measurable separations of X-ray terms. A nucleus having a spin of 9/2 (in units of $h/2\pi$) and a magnetic moment 9/2 in protonic units should cause the K-terms of the heaviest elements to split into two components separated by about 22 volts. Such separations require for their detection a resolving power of 4200. For lighter elements the effect is relatively smaller. The same nuclear spin and magnetic moment would cause a separation of only 0.9 volt in Mo which would require for its detection a resolving power of 1.9×10^4.

The calculations are made using Dirac's equation for a single electron without approximations. The effect of electrons in other shells, however, is neglected. It is estimated to be very small for a single K-electron. If the observation of hyperfine structures in the K-series of the heavier elements proves feasible, it should offer a simple means of determining magnetic moments of nucleii having a known spin.

The fine structure of He as a test of the spin-interactions of two electrons. G. Breit.

A tentative expression for the quantum Hamiltonian of two electrons set up in a previous paper is discussed again. It is shown that the last term in it is subject to doubt. The Hamiltonian is tested by applying it to the calculation of the fine structure of the He 2^3P-level. It is found that the above-mentioned term in e^4 is in contradiction with experiment. Removing the term from the equation one is left essentially with Heisenberg's old Hamiltonian. The spin-interaction in it is shown to agree well with experiment. The calculation has been applied also to Li^+.

The essential improvements on previous work are: (1) An increase in the precision of the unperturbed eigenfunctions; (2) a determination from experimental data of a constant D which depends directly on spin-spin-interactions and which can be calculated with fair accuracy. Comparing the theoretical and empirical values of D a clearer test of the magnitude of spin-spin-interactions can be obtained than by calculating the relative positions of the three components of the triplet. The reason for this is that the relative positions of the lines depend also on another constant C which is a difference of two approximately equal numbers and is more difficult to calculate accurately.

Note on frequency-shifts in dispersing-media. G. Breit and E. O. Salant.

The propagation of a light-wave through a dispersing-medium is discussed. The absorption-frequencies of the medium are shown to be equal to the absorption-frequencies of the coupled system formed by molecules contained in a cavity elongated in the direction of the electric intensity of the incident light-wave. The cavity contains a large number of molecules but is small in comparison with the wave-length.

The absorption-bands of the coupled system are discussed. For tenuous media the shift is small and of the order of the Lorentz-Lorenz shift. The modification due to the quantum theory consists in replacing the classical $e^2/8\pi^2m\nu$ by $|X(\mathrm{I}, \mathrm{II})|^2$, where $X(\mathrm{I}, \mathrm{II})$ is the unperturbed matrix-element of the polarization in the fixed direction X. The normal state is I and the excited state is II. In this approximation the shift is obtained by replacing the classical e by Dennison's effective charge. For regular arrangements of molecules no broadening due to coupling is expected.

For dense media there are additional effects even to the first order. These are: (1) The electrostatic interaction of a molecule with its neighbors due to excitation, and (2) the effect of the finite space-extension of the $u^*_{\mathrm{I}}u_{\mathrm{II}}$ charge-distribution. A comparison of the measured shifts in liquid HCl and HBr with the extrapolation of the Lorentz-Lorenz formula modified by $|X(\mathrm{I, II})|^2$ is made. The observed shift is much too large to be explained without taking into account effects (1), (2). Particle-exchange has been neglected.

A laboratory method of producing high potentials. G. Breit, M. A. Tuve, and O. Dahl. Phys. Rev., vol. 35, 51-65 (January 1, 1930).

Details are given of the experimental arrangements by which, using Tesla coils in oil, very high potentials have been produced and measured. Excited at the rate of 120 sparks per second, Tesla coils have been operated at 3,000,000 volts in ordinary transformer oil at atmospheric pressure. In oil under a pressure of 500 pounds per square inch, voltages as high as 5,200,000 have been produced with intermittent excitation. These voltages (peak-values) are measured by a simple capacity-potentiometer, in which an insulated electrode "picks up" a known fraction of the total voltage, this fractional voltage being measured by means of a sphere-gap. Measurements are given of the voltage-distribution along Tesla coils. Calculations and measurements of the efficiency and power-output of such coils show that at 120 sparks per second a coil operating at 5,000,000 volts provides sufficient power, if used to accelerate helium nuclei in a suitable vacuum-tube, to yield the equivalent of about 2600 grams of radium.

The effect of condensation-nuclei in atmospheric-electric observations. G. Builder. Terr. Mag., vol. 34, 281-286 (December 1929).

Curves are given, based on observations made at the Watheroo Magnetic Observatory, showing the relations found between the counts of condensation-nuclei made with an Aitken counter and the simultaneous values of the atmospheric conductivity and potential-gradient. There is some disagreement with the data given by Wait, based on fewer observations. It is concluded that, for the range of observation, there is an approximately linear relation between the nuclei-count and the reciprocals of the polar conductivities and between the nuclei-count and the potential gradient. Owing particularly to the influence of the distribution of the pollution with respect to height, the potential-gradient curves are not very definite. The effect of the pollution on the conductivity is expressed in terms of the linear recombination-law of Schweidler and the extension of this to explain the effect of high values is noted. An approximate and non-linear extrapolation of the curve for reciprocals of negative conductivity against nuclei-count is given based on Schweidler's equation of recombination in the presence of Langevin ions and uncharged nuclei.

Preliminary note on atmospheric potentials recorded with ionium-collectors. G. Builder. Terr. Mag., vol. 35, 35-41 (March 1930).

The paper discusses a laboratory investigation of the characteristics of ionium-collectors as a preliminary to a fuller investigation of the potentials recorded by their use in atmospheric potential-gradient installations. Earlier work by J. E. I. Cairns and the author on the permissible leak of such installations and the determination of the activity of the collectors is further developed. The results of the investigation are compared with those of Moulin and of Tuve and Huff.

Med bil og husbat i Asia. O. Dahl. Oslo, Gyldendal Norsk Forlag, 222 with illus. (1929).

This volume is an illustrated popular account of the author's expedition in Syria, Iraq, Persia, Baluchistan, and India during June 1928 to May 1929, in the course of which magnetic secular-variation data were obtained.

Note on the computation of the moment of inertia of a magnet and its suspension. C. R. Duvall. Terr. Mag., vol. 34, 303–308 (December 1929).

An abstract of this paper is given on page 252 of the annual report for 1928–1929.

Preliminary note on a measure of magnetic activity using an ordinate-change integrator. C. R. Duvall. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., August 1930, 61–64 (June 30, 1930).

This preliminary note describes the proposed use of the increment-sum of ordinates of a photographic or other automatic record, such as a magnetogram, as a measure of the activity of the phenomenon recorded. Following some brief general considerations leading to the method of treatment of the results, a summary of measurements of the three elements on the magnetograms of March 1927 at Watheroo and Huancayo is given.

Memorandum regarding frequency of errors. C. R. Duvall.

A short table by Gauss is reproduced which gives the frequency of error in terms of multiples of the probable error. A brief explanation of the computation and use of this table is given.

On corrections to amplitudes and phase-angles computed by harmonic analysis for noncyclic changes assumed to be linear. C. C. Ennis. Trans. Prague Meeting, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., September 1927. Bull. No. 7, 225 (June 1929).

Preliminary sonic-depth results on Cruise VII of the *Carnegie*. C. C. Ennis.

This is a preliminary compilation briefly describing instruments, work at series-stations, correction-factors, and some of the new bottom-features revealed on the courses followed by the *Carnegie*, May 1928 to November 1929.

In tribute to the memory of James Percy Ault. H. W. Fisk. Terr. Mag., vol. 34, 279–280 (December 1929).

Secular variation of magnetic intensity and its accelerations in Pacific countries. H. W. Fisk. Proc. Fourth Pacific Science Congress, Java, 517–534 (1929). (Abstract) Jour. Wash. Acad. Sci., vol. 20, 13–15 (January 4, 1930).

This paper is abstracted on pages 254–255 of the annual report for 1928–29.

Regional distribution of magnetic secular-variation over the Earth's surface.[1] H. W. Fisk. Pub. Nation. Res. Council, Trans. Amer. Geophys. Union, 10th and 11th annual meetings, 215–223 (June 1930).

Isopors and isoporic movements. H. W. Fisk. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., August 1930, 23–30 (June 30, 1930).

From the secular-variation data now available, it is possible to construct world charts of the magnetic isopors (lines of equal annual change of the different elements) with an attempt to fill in details not hitherto warranted. Such charts for declination, inclination, and horizontal intensity are presented with the first of the above papers, and in the accompanying discussion some interesting conditions are noted. For each of the elements there are a number of "foci" around which the isopors form a compact series of concentric closed ovals, the annual change of that element at the center being unusually large. The most active foci are grouped around the land masses on either side of the Atlantic Ocean, there being none of importance found either in the Pacific Ocean or on the lands bordering upon it. The activity in the vicinity of the foci is variable, which implies the growth or decay of the systems of isoporic ovals, and in some cases a well-marked shift of the point of maximum change. The series of observations by which these movements are detected is at present too short to make it possible to say whether growth and decay occur in successive alternations, though changes which have occurred within the 25 years covered by observatory-records and magnetic surveys suggest the possibility. The horizontal intensity is increasing nowhere in the Southern Hemisphere with the exception of a very small area near the mouth of the Amazon and a somewhat larger region in the northern part of the Indian Ocean. It is increasing in but a portion of the Northern Hemisphere, there being but one positive focus, a very moderate one in southern India, while there are two very strong negative foci, one in northern Eurasia and one in the West Indies.

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[1] Presented at the meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, May 2, 1930.

Among the noteworthy movements of isopors, or accelerations of secular rates, mention is made of the development of the declination-focus in western Europe since 1905, the disappearance of positive intensity-focus from the Amazon valley since 1917, the recent contraction of the ovals about the Ecuador-Colombia positive inclination-focus simultaneous with the dilation of the west Africa negative inclination-focus, and the drift of the positive intensity-focus in southeastern Asia from southern China to southern India.

Further evidence that the Atlantic is a region of interest in the study of secular variation is found in the examination of the acceleration of the declination-rates at observatories on opposite sides. That acceleration, instead of being uniform, varied considerably during the 24 years prior to 1926, and when the departures of the annual rates from uniformly changing rates are plotted for the observatories in western Europe the curve in each case is sinusoidal, with a maximum about 1911 and a minimum about 1918. When curves for Cheltenham and Agincourt are plotted in the same way, they are similar in form to those for Europe but are inverted, having a minimum instead of a maximum at the earlier date and a maximum corresponding to the minimum at the European observatories. Similar curves for Samoa and Honolulu have no resemblance to the European and North American curves, indicating the improbability of an extra-terrestrial cause.

Secular variation, therefore, seems not to be a phenomenon arising from causes affecting all parts of the Earth and so distributed as to be readily discussed by the usual methods of harmonic analysis. A portion may be and probably is thus caused, but it is obvious that a large part of the whole change, which perhaps ought not to be called secular, has its origin in processes going on in the interior of the Earth, and should be studied in its relation to other geophysical problems.

The second paper includes isoporic charts for total and vertical intensity, and treats the same subject-matter as the foregoing with especial reference to its interest as a subject for international cooperation.

On the distribution of permanent repeat-stations. H. W. Fisk and J. A. Fleming. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., August 1930, 31–35 (June 30, 1930).

Some principles to be considered in the selection of sites for new magnetic observatories and for permanent repeat-stations are presented, and comments are made as to the desired frequency of reoccupation. These are based upon the consideration of the character of the accelerations of secular rates in various regions. Two charts, one for each hemisphere, show the proposed locations of repeat-stations and observatories.

Secular variation in the North Atlantic from observations aboard the *Carnegie*, 1910–1928. H. W. Fisk.

The discussion of secular-variation rates of all the magnetic elements on all continents bordering on the Atlantic Ocean points to conditions of especial interest in those waters. On the North Atlantic particularly, a comparatively large number of observations have been made by the *Carnegie* on the various cruises along tracks which intersect at many points. The points of intersection, however, are relatively far apart when the character of the distribution of secular changes is considered, and the interval of time included between the dates of the intersecting courses at neighboring intersections often differ widely and refer to a different mean-year. Furthermore, there is reason to suspect that peculiar combinations of ship's motion with magnetic bearing of the course occasionally produce anomalous results which should not be included in the groups of which the means are taken, provided a safe criterion for rejection can be discovered.

The method of computing the most probable rate of change of the element with position in passing along a straight or slightly parabolical line to which the positions of the points of observation are adjusted, was used for most of the courses followed on the various cruises in the North Atlantic, and has given good results in those cases where the stations were not too far apart and where the distribution of the element is fairly regular. However, when the distances between stations are great, where the tracks followed departed widely from straight lines, or where the isomagnetic lines representing the distribution of the element as shown on the isomagnetic chart were sharply curved, the results were not satisfactory.

The importance of deriving from the *Carnegie* observations as much information regarding the secular-variation rates and their accelerations during the past two decades as their distribution and accuracy permit warrants further investigations of methods which promise useful results. The process of referring all observations to the same chart, which was adopted by Ault in the preparation of the preliminary results which have been published, is capable of development so that a larger number of secular-variation values may be derived and a criterion established for the rejection of anomalous results. The rate of change of an element per degree of latitude or of longitude is altered but slightly from year to year by the changes arising from secular variation, and these changes can be derived with considerable accuracy from reliable charts such as the most recent ones of the North Atlantic Ocean by adjustment of the scaled values to a suitable equation. By means of such rates, all the values along two approximately parallel courses not too widely separated may be referred to the same meridian or parallel, and rates derived for as many points along that meridian or parallel as may be desired. For example, Cruise IV leaving Gardiner's Bay in 1915 and Cruise VI returning to Washington in 1921 followed tracks roughly parallel not far from the meridian of 75° west longitude. The secular change in horizontal intensity along this meridian, which passes through a region of very large rates for this element, confirms and supplements the results derived from island observations in the West Indies. In a similar way Cruise II returning to New York in 1913 and Cruise VI outward bound in 1919 follow courses not far from the parallel of 37°.5 north latitude but do not intersect until in the vicinity of the Azores. The negative rates of horizontal intensity in the vicinity of New York gradually diminish until meridian 42° west is reached, after which positive rates slowly increase toward the east. The number of places where this method can be applied is not large but, with some modification in procedure, it can be employed to provide much useful information not supplied by a consideration of the points of intersection alone. The limiting factor is the inherent error of observation by methods used at sea. These errors may be systematic over a considerable portion of a course in a given direction and are not susceptible of detection and correction by analysis of this kind.

Report on work of Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, 1925–1927. J. A. Fleming. Trans. Prague Meeting, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., September 1927. Bull. No. 7, 139–141 (June 1929).

Memorandum regarding report on the work of the Section of Terrestrial Magnetism and Electricity of the French Committee of Geodesy and Geophysics for the Prague Meeting. J. A. Fleming. Trans. Prague Meeting, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., September 1927. Bull. No. 7, 214 (June 1929).

Die Katastrophe der Yacht *Carnegie*. J. A. Fleming. Beitr. Geophysik, vol. 25, 130 (1930).

The *Carnegie's* seventh cruise. J. A. Fleming. Beitr. Geophysik, vol. 26, 5–13 (1930).

The last cruise of the *Carnegie*. J. A. Fleming. Terr Mag, vol. 35, 22–28 (March 1930).

Progress of the *Carnegie's* seventh cruise. J. A. Fleming and J. P. Ault. Proc. Internat. Oceanogr. Congress, Seville, 147–160 (1929).

Cruise VII of the *Carnegie* 1928–1931 in the Pacific and Indian oceans. J. A. Fleming and J. P. Ault. Proc. Fourth Pacific Science Congress, Java, 547–560 (1929).

Resultados del séptimo crucero del *Carnegie*. J. A. Fleming and J. P. Ault. Madrid, Mem. Consejo Oceanogr. Ibero-Americano, No. 3, 19 pages (March 31, 1930).

The *Carnegie* and her last commander. J. A. Fleming and F. F. Bunker. Carnegie Inst., News Service Bull., vol. 2, No. 1, 1–9 (1930).

The seventh cruise of the *Carnegie*.[1] J. A. Fleming. Pub. Nation. Res. Council, Trans. Amer. Geophys. Union, 10th and 11th annual meetings, 251–257 (June 1930).

Observations of terrestrial magnetism and atmospheric electricity on the last cruise of the *Carnegie*. J. A. Fleming. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., August 1930, 19–22 (June 30, 1930).

Oceanographic work done on the non-magnetic ship *Carnegie* during her seventh and last cruise. J. A. Fleming. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., August 1930, 79–86 (June 30, 1930).

These ten articles relate to various phases, generally descriptive, of the scientific program and progress during Cruise VII of the *Carnegie*. The last three summarize in more detail the work that had been accomplished before the catastrophe November 29, 1929, in which the vessel was destroyed and Captain Ault and Cabin-Boy Kolar lost their lives.

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[1] Presented at the meeting of the Section of Oceanography of the American Geophysical Union, Washington, May 1, 1930.

Summary of the year's work, Department of Terrestrial Magnetism, Carnegie Institution of Washington. J. A. Fleming. Terr. Mag., vol. 35, 43–46 (March 1930).

This article summarizes briefly the outstanding features of the work done by the Department of Terrestrial Magnetism during the year ending June 30, 1929, which is given in more detail in the Department's annual report for the year.

The postponement to 1931 of Aeroarctic's first expedition. J. A. Fleming. Science, n. s., vol. 71, 280–281 (March 14, 1930).

International Geodetic and Geophysical Union (actions pertaining to standards, standard instruments, and nomenclature). J. A. Fleming. Standards Year Book 1930. Dept. Comm., Bur. Stan. Misc. Pub. No. 106, 22–24 (1930).

This note briefly summarizes actions and publications of the International Geodetic and Geophysical Union and of the American Geophysical Union during the year which are of interest to or have bearing on standards and nomenclature.

Transactions of the American Geophysical Union, tenth annual meeting, April 25 and 26, 1929; eleventh annual meeting, May 1 and 2, 1930. J. A. Fleming, Editor. Pub. Nation. Res. Council, 314 pages (June 1930).

Latest annual values of the magnetic elements at observatories. J. A. Fleming. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., August 1930, 36–50 (June 30, 1930).

Report on the work done since the Prague Assembly. J. A. Fleming. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., August 1930, 5–18 (June 30, 1930).

This report summarizes briefly, for the information of the Stockholm Assembly of the International Geodetic and Geophysical Union in August 1930, the work done by the Department of Terrestrial Magnetism in the three years June 30, 1927, to June 30, 1930, in the fields of terrestrial magnetism and electricity. There is some account of operations bearing upon resolutions adopted at Prague. A selected bibliography of publications by the Department is given.

On "non-cyclic corrections" at the Watheroo Observatory. J. A. Fleming and H. M. W. Edmonds. Trans. Prague Meeting, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., September 1927. Bull. No. 7, 221–224 (June 1929).

The results of discussions of observatory data from the Watheroo Magnetic Observatory bearing on application of "non-cyclic" corrections are given from which it is concluded that such corrections should not be applied in tabulating the hourly values of magnetic data or in making harmonic analyses of diurnal variations. It is quite readily possible to apply corrections to computed amplitudes and phase-angles for any set of data to take account of any "non-cyclic" corrections that may later be decided are proper. (For a detailed summary, see pages 249–250 of the annual report for 1927–28.)

Summary of magnetic-survey work by the Carnegie Institution of Washington. J. A. Fleming and H. W. Fisk. Trans. Prague Meeting, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., September 1927. Bull. No. 7, 205–213 (June 1929).

This article reviews and summarizes through charts and tables the magnetic-survey work of the Department during 1905–26. The distribution of secular-variation stations is discussed, as also the general developments of instruments and methods for observations. (See also abstract on pages 250–251 of annual report for 1927–28.)

Preliminary notes on intensity-constants of C. I. W. magnetometers. J. A. Fleming and H. W. Fisk. Trans. Prague Meeting, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., September 1927. Bull. No. 7, 234–238 (June 1929).

An abstract of this paper is given on pages 251–252 of the annual report for 1927–28.

The Meinesz gravity-apparatus on the *Carnegie*. S. E. Forbush.

The Meinesz gravity-apparatus on the *Carnegie*.[1] S. E. Forbush and O. W. Torreson. Pub. Nation. Res. Council, Trans. Amer. Geophys. Union, 10th and 11th annual meetings, 137–140 (June 1930).

The first of these papers is a detailed report on the installation at San Francisco in August 1929 of and experiments with the Meinesz gravity-apparatus on the *Carnegie* until the time of the vessel's destruction at Apia. The second is a condensed summary. Acknowledgment is made of the cooperation of various individuals and organizations both in the United States and abroad, which made possible the installation of the apparatus on the *Carnegie*. The account of arrangements for time-control is followed by a brief description of the essential features of the instrument. Results of observations while in harbor at San Francisco and while at sea, and the conditions under which the measurements were made are discussed and certain difficulties pointed out. Efforts to remove the major difficulties and to improve the operation of the apparatus are described as being only partially successful and the paper concludes with a statement from Dr. Meinesz, describing his experience with a similar apparatus on board a steamer during a trip from Holland to Netherlands East Indies in April 1929, in which he met with difficulties similar to those encountered on the *Carnegie*. The conclusion which may be drawn is that further experimentation is necessary and that certain modifications are desirable in order to obtain consistently successful results on surface vessels.

Remarks on "The efficiency of quenching collisions and the radius of the excited mercury atom" E. Gaviola. Phys. Rev., vol. 34, 1049–1051 (October 1, 1929).

An abstract of this paper is given on page 258 of the annual report for 1928–29.

On life and concentration of metastable atoms and the quenching of mercury resonance radiation. E. Gaviola. Phys. Rev., vol. 34, 1373–1384 (November 15, 1929).

An abstract of this paper is given on page 258 of the annual report for 1928–29.

On the reliability of earth-current potential measurements. O. H. Gish. Trans. Prague Meeting, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., September 1927. Bull. No. 7, 247 (June 1929).

On the relatively large values of earth-current potential recorded at the Ebro Observatory. O. H. Gish. Trans. Prague Meeting, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., September 1927. Bull. No. 7, 248–249 (June 1929).

Note on Dr. Nakumura's communication ("The disturbance of the earth-potential during the total solar eclipse of June 29, 1927, observed at Sendai, Japan"). O. H. Gish. Trans. Prague Meeting, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., September 1927. Bull. No. 7, 251 (June 1929).

Comments following a paper entitled "Pipe-line currents" by K. H. Logan, Walter Rogers, and J. R. Putnam, before the ninth annual meeting of the American Petroleum Institute at Chicago, Illinois, December 5, 1929. O. H. Gish. Amer. Pet. Inst., Proc. Tenth Annual Meeting, Sec. 4, vol. 11, 121 (January 2, 1930).

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[1] Presented at the meeting of the Section of Geodesy of the American Geophysical Union, Washington, May 1, 1930.

The atmospheric dynamo-theory of variations in earth-currents and terrestrial magnetism —a review. O. H. Gish. Pub. Nation. Res. Council, Trans. Amer. Geophys. Union, 10th and 11th annual meetings, 77 (June 1930).

The significance of atmospheric-electric observations at sea.[1] O. H. Gish. Pub. Nation. Res. Council, Trans. Amer. Geophys. Union, 10th and 11th annual meetings, 190–197 (June 1930).

The importance of atmospheric-electric observations at sea. O. H. Gish. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., August 1930, 69 (June 30, 1930).

Atmospheric-electric observations at sea on the ship *Carnegie* have shown that the electrical state of the atmosphere over the ocean-areas is little affected by local factors such as give a confusing complexity to these phenomena over land. This circumstance, together with the wide geographical distribution of observations, which can be obtained with a cruising observatory, has made it possible to derive from a comparatively small number of ocean-data definite conclusions of fundamental importance to the science. These two papers emphasize the results showing this as obtained on Cruise VII of the *Carnegie*. Illustrations include the recording instruments first used on Cruise VII of the *Carnegie* and records obtained with these which bring out vividly the greater uniformity and simplicity of atmospheric-electric conditions at sea.

Note on earth-current storm, July 31–August 1, 1929. O. H. Gish. Terr. Mag., vol. 35, 113–114 (June 1930).

Natural electric currents in the Earth's crust.[2] O. H. Gish.

Natural electric currents in the Earth's crust were discovered through their occasional disturbing effect on telegraph lines. Knowledge of their relation to other phenomena has been furthered chiefly by observation with special equipment in regions free from disturbing currents of artificial origin. A description of these currents and their relation to some aspects of terrestrial magnetism, radio-transmission, and polar lights is given. Evidence is presented which leads to the view that the immediate origin of these currents is found high in the Earth's atmosphere, and that this source is in turn influenced by processes in the atmosphere of the Sun.

A remarkable feature of earth-currents displayed by the storm of July 31–August 1, 1929. O. H. Gish and W. J. Rooney.

The earth-current storm which began suddenly at 21^h G. M. T. July 31, 1929, received special attention in the first place because of some observations of the potential gradient in oil pipe-lines in California, made by K. H. Logan and cooperating parties, as part of a study of the corrosion of such lines. When this work first came to the authors' attention the earth-current records from Watheroo (Western Australia) alone were at hand for comparison. It was, however, at once evident from the close similarity between the California pipe-line records and the Watheroo earth-current records that the chief variations in the former were due to the earth-current storm. Fortunately the data from the pipe-lines are such as to give the approximate direction of current-flow in the Earth. There are records also available from the Huancayo Magnetic Observatory (Huancayo, Peru), the Ebro Observatory (Tortosa, Spain), and the American Telephone and Telegraph Company (the last on lines running out of New York City). The simultaneity and similarity of character of many changes at all of these five widely distributed places is unmistakable. There are, to be sure, changes which do not stand in this agreement. This much might have been expected from our knowledge of the characteristics of magnetic storms and their relation with earth-current storms. However, an entirely unexpected and remarkable feature was disclosed by this comparison. This was that for certain components of this storm the direction of current-flow was nearly the same at all of these five widely distributed places. The sudden commencement brought this out most vividly. It consisted of a current-pulse which was directed in a general northwesterly direction at all stations. If the flow had been found to take place along an east-west line, then it would have been in harmony with most theories of magnetic storms. But the conflict which these observations present, taken together with the phase-relation so commonly found between earth-current and magnetic-storm variations, suggests the need of a radical departure in the theoretical attack on this problem.

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[1] Presented at the meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, May 2, 1930.

[2] Lecture delivered at the Carnegie Institution of Washington, April 15, 1930.

A model suggested by the observations just described, and by other known facts regarding earth-currents at times of storm, is in the main as follows: A ring-system of currents, which flow along parallels of latitude, is combined with a meridional system which flows from one polar region to the other. The former is probably induced by an external ring-system, such as has been suggested in theories of magnetic storms. The latter may belong to a non-potential system, although no feasible mechanism for this is at present in view.

Results of earth-current observations at Huancayo Magnetic Observatory, 1927–1929. O. H. Gish and W. J. Rooney.

The earth-current potential-records from the Huancayo Magnetic Observatory have now been evaluated for the years 1927, 1928, and 1929. The diurnal variation in potential gradient for the northward component has a mean range of 2.83 mv/km., with a pronounced maximum shortly after 9^h and a less sharply defined minimum at about 15^h. The diurnal-variation curve for the eastward component is remarkably similar to that for the northward, except that its sign is reversed and its mean range, 3.26 mv/km., is slightly greater. This amplitude- and phase-relation between the two components remains unchanged in the diurnal-variation curves for the individual months of the year. Hence it appears that the flow of earth-currents at this site is restricted almost entirely to a direction approximately 49° west of north, the current flowing to the northwest during the daylight-hours before noon and toward the southeast from noon until sunset. The currents during the night-hours are small and fluctuating.

The mean diurnal-variation curves for the three individual years are all in very close agreement, both as to range and general appearance. The seasonal variation in diurnal range (from hourly means by months) is alike for both components and very similar to that observed at Watheroo.[1] The ranges (1.89 mv/km. for the northward component and 2.18 mv/km. for the eastward) are least in June (mid-winter) and greatest at the time of the equinoxes when they reach about 3.50 mv/km. and 4.00 mv/km., respectively.

Harmonic analyses show a predominant first harmonic throughout the year for both components. Second and third harmonics with amplitudes from 80 to 90 and 40 to 50 per cent of the first are also present. The seasonal variation in the amplitudes of the individual harmonics is very like that of the range of the diurnal-variation curve. In these analyses the data for system I are used because of the greater uniformity of the ground-structure in the region covered by that system. The superiority of the location of this system over that of system III has been emphasized by the results of the earth-resistivity survey made there during 1929 (see p. 312). The records from system III lead to essentially the same conclusions when account is taken of the variation in the resistivity of the region it covers.

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[1] See Terr. Mag., vol. 33, 79–90 (June 1928).

The diurnal range in mean hourly potential-gradient here is about four times that found at Watheroo. However, the average resistivity of this region is at least ten times as great; hence the current-density is not more than 40 per cent of that at Watheroo.

Errors in electric-field measurements with a radioactive collector. O. H. Gish and K. L. Sherman.

A laboratory investigation of the action of ionium-collectors used by the Department for measuring air-potentials has been under way, intermittently, since October 1928. Considerable difficulty was encountered at first in obtaining uniform fields between parallel plates set up for this purpose. Using plates two meters square and as close as 50 cm., the field was stronger near the plate which was not earthed, regardless of whether it was the top or bottom plate. This non-uniform field was not due to the use of ionium-collectors since it was found to exist when the field was explored with a water-dropper. It was found necessary to use side-screens, connected to the mid-point of the batteries which maintained the potential on the plates, in order to obtain a uniform field throughout the distance from plate to plate. With this arrangement and with the plates one meter apart the field was found uniform in a considerable part of the central space.

The observations of Builder and other observers, in which they found that the air-circulation influenced both the apparent conductance of the collector and also the final potential which the collector-system assumed, were qualitatively confirmed, except that, while Builder reported the potential assumed by the collector to be always greater in stagnant than in circulating air, it was here found that this depended on the position of the collector relative to the plates. This was found before Builder's results were known. After his manuscript came to our attention, further observations were made with this point of disagreement especially in mind. It was found that for positions between the top plate and a point somewhat below the center, greater values were measured and for positions below this the collector acquired a lower potential in stagnant air than in circulating air.

A plausible explanation of the major aspects of these observations is that a space-charge collects near the plates. This view is borne out by the fact that when using several collectors the effect is greater than with one, and also by the observation that if a current of air directed near and parallel to one plate increases the effect, then when this current is directed along the other plate the effect is decreased. The fact that the neutral point is somewhat below the mid-point, irrespective of the direction of the field, and, when disc-type collectors are used, irrespective of whether the radioactive material faces upwards or downwards, is not explained.

From these experiments it would appear that in potential-gradient observations the measured values tend to be too low during times of extreme calm. However, the air-circulation in the open is doubtless generally sufficient to disperse the space-charge arising from this source and thus eliminate this source of error. It is apparently only in the case of fields in the laboratory that artificial circulation must be provided when a radioactive collector is used.

Potential gradient at Washington, D. C., 1924 to 1928. O. H. Gish and K. L. Sherman.

During the earlier years of air-potential registrations at Washington (1917–1923) the factor for reducing these to the gradient over a plane was determined rather infrequently and this value varied considerably from time to time. From the year 1924 on, however, the factor was determined more frequently and, although large variations were found, this feature was much improved. The improved condition is attributed chiefly to the completion in the early part of 1924 of the larger, nearby real-estate projects in which steam-shovels were used for grading. In view of the fact that these factors showed no regular periodic changes during the year but were undergoing regular changes from year to year, the following method of adjustment was adopted: The mean factor for each year was plotted against the mean time of year; the factor for each month was then taken from the resulting graph.

The annual means of the potential gradient for the five years 1924–1928 are in order: 156, 149, 161, 179, and 168 volts per meter. These values differ considerably from the annual means previously reported which were based on a tentative reduction-factor.

The mean diurnal-variation characteristics for this period are given by the Fourier expression

$$P = 163 + 33.5 \sin (\theta + 237^{\circ}\!.9) + 19.3 \sin (2\theta + 175^{\circ}\!.8) + 8.0 \sin (3\theta + 19^{\circ}\!.9) + 5.4 \sin (4\theta + 290^{\circ}\!.2)$$

where P is the potential gradient in volts per meter and θ is counted from midnight 75th meridian time at the rate of 15° per hour. From this the maximum of the 24-hour term occurs at $19^{\mathrm{h}}1$ G. M. T. The phase-angle of this term was found to vary in an approximately periodic manner throughout the year, having a maximum of $191^{\circ}\!.5$ in April and a minimum of $134^{\circ}\!.5$ in August, this being in rough agreement with results obtained on the *Carnegie* as well as with the theory of Wait and Sverdrup.

Investigation of temperature-effects in Department of Terrestrial Magnetism conductivity-records. O. H. Gish and K. L. Sherman.

Following an investigation of the variation of conductivity scale-value with temperature made by Wait (Annual Report 1928–1929, p. 273), the potential sensitivity of the electrometers used on the air-conductivity recorders at the Department's observatories was regularly determined at the time of the conductivity-calibration. With this extra datum it has been possible to ascertain the extent to which the temperature-effect was dependent upon the electrometer. It also made possible a more satisfactory treatment of the data because changes in sensitivity from whatever causes could be eliminated, thus giving a more homogeneous mass of data for studying the variation of the conductance of the Bronson-type cell, which was suspected as being the chief source of the temperature changes.

The sensitivity of the electrometers underwent changes due to adjustments from time to time. Slow progressive changes were also in evidence in some cases. The frequency of the former excluded the determination of a temperature-coefficient for one of the four electrometers from these data, and such coefficients as were determined are not wholly free from these effects. However, it appears that the electrometer-sensitivity does vary with temperature. The coefficients found were +0.2, +0.3, and −0.8 per cent per degree Centigrade. The temperature-coefficients of the conductance of the Bronson cells were 0.8, 1.1, 1.8, and 0.4 per cent per degree Centigrade, all these being positive.

Since the conductivity-apparatus is calibrated once each week, the annual change in temperature is not a matter of concern. Irregular changes during the month and the diurnal temperature-changes may, however, introduce some errors. The diurnal range of temperature in the atmospheric-electric buildings at the observatories amounts on the average to about 3° C. Hence it is possible that a spurious diurnal-variation in the conductivity amounting to 5 per cent in the extreme case may be introduced into the data from this instrumental cause. This is not serious for such studies of the data as are at present in sight, but is rather more than one cares to tolerate. However, the short-time changes in temperature may not produce the same responses in a Bronson cell as long-time changes. Since it was chiefly data of the latter class that were used in the present study, it may not be safe to deduce from this the magnitude of the effect for short-time changes of temperature. The data for appraising these can be obtained best from laboratory experiments.

Recent magnetic observations in South and Southwest Africa.[1] E. N. Grindley.

This paper discusses the results of a resurvey of parts of South Africa, conducted by the author for the Department of Physics of the University of Cape Town in cooperation with the Department of Terrestrial Magnetism. The first survey of the region was made by Sir Carruthers Beattie and Professor J. T. Morrison between 1898 and 1906. Some additional but scattered observations were made in 1908 and 1909 in cooperation with the Department of Terrestrial Magnetism and in 1912–1913 by Sir Carruthers Beattie, and in 1916 by Observer H. E. Sawyer of the Department. As there is no magnetic observatory in South Africa, it was necessary to rely on a few series of diurnal-variation observations made in the field for the data required to correct results for diurnal inequality. It was found that the declination is changing toward the east over the whole area, the rate accelerating apparently until 1912, with a slight indication of a retarded rate since the observations of 1916. There appears to be a center or focus of rapid change somewhere in the sea east of East London, and evidence is adduced that this focus is shifting toward the south. Drawings were prepared showing the distribution in July 1928 of the three elements and the lines of equal annual change. Diurnal variation as determined from the field observations is also discussed, but because of the small number of the days upon which these were made, and on account of regional, seasonal, and anomalous conditions which affect the curves for individual days, they are used tentatively until more reliable results can be obtained.

A new method of observing diurnal variation of magnetic intensity and declination with field instruments.[2] E. N. Grindley.

In this paper the author sums up and discusses the comparative advantages and disadvantages of the two generally used methods of conducting these observations, namely, that by means of deflections repeated at short intervals and that by oscillations. The author's preference is for the method of oscillations, chiefly on account of the difficulty of controlling temperature-changes inherent in the method of deflections, and to some extent because of the inconvenience of the deflection-bar in the tent in a region where high winds are prevalent.

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[1] Presented at the meeting of the British Association for the Advancement of Science, Cape Town, South Africa, July 1929.

[2] Presented at the meeting of the South African Royal Society, Cape Town, South Africa, July 1929.

Design of vacuum prebaking-furnace. L. R. Hafstad and O. Dahl. Rev. Sci. Instr., vol. 1, 517–522 (September 1930).

A description is given of a simple type of vacuum prebaking-furnace which has proved to be both economical and serviceable. The design embodies the experience of several laboratories with such furnaces so that most of the troublesome features and unnecessary complications have been eliminated. While this particular design is not unique and may be readily modified, the description does call attention to a number of important considerations which must be taken into account in building any furnace of this kind.

James Percy Ault, 1881–1929. H. D. Harradon. Terr. Mag., vol. 34, 273–278 (December 1929).

A biographical sketch of Captain James Percy Ault. H. D. Harradon. Beitr. Geophysik, vol. 26, 1–4 (1930).

List of recent publications. H. D. Harradon. Terr. Mag., vol. 34, 266–272 (September 1929); 332–338 (December 1929); vol. 35, 56–60 (March 1930); 110, 120–124 (June 1930).

This list is a bibliography of current literature relating to (*A*) terrestrial and cosmical magnetism, (*B*) terrestrial and cosmical electricity, and (*C*) miscellaneous subjects allied to (*A*) and (*B*). The compiler has prepared in many cases for the more important publications brief abstracts which are included with the references.

The library of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. H. D. Harradon. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., August 1930, 76 (June 30, 1930).

Ordinate-change integrator. C. Huff. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., August 1930, 58–60 (June 30, 1930).

This article describes briefly the design and construction of the special instrument for integrating total positive and negative ordinate-change—the ordinate-change integrator—of any variation record such as a magnetogram, electrogram, etc. This instrument has been designed particularly to test possibilities of determining a measure of activity of such a record directly and quickly.

On terminology and symbols in atmospheric electricity. H. F. Johnston. Trans. Prague Meeting, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., September 1927. Bull. No. 7, 241 (June 1929).

Principal magnetic storms recorded at the Watheroo Magnetic Observatory: January to May 1929; June to December 1929. H. F. Johnston. Terr. Mag., vol. 34, 263 (September 1929); vol. 35, 53–54 (March 1930).

Annual changes in the magnetic elements in the north and central Pacific Ocean. H. F. Johnston.

All of the magnetic observations made by the *Galilee*, 1905–1908, and the *Carnegie*, 1909–1929, in the area of the ocean under discussion have been utilized to determine the annual changes. They are being inter-referred by using the United States Hydrographic Office isomagnetic charts Nos. 1700, 1701, and 2406 for 1930. The changes being obtained are consistent with those shown on recent charts.

Cosmic phenomena influencing the propagation of radio waves. A. E. Kennelly.

This paper discusses various problems bearing on effects on radio waves of terrestrial magnetism, terrestrial electricity, solar, and cosmic phenomena. Some account of researches being made at the Watheroo and

Huancayo observatories of the Department is given. The paper also briefly summarizes the character of the daily broadcast of cosmic phenomena to be begun by August 1930 from the United States and of the part American organizations including Science Service will take.

Further observations of radio transmission and the heights of the Kennelly-Heaviside layer. G. W. Kenrick and C. K. Jen. Proc. Inst. Radio Eng., vol. 17, 2034–2052 (November 1929).

The results of further observations on radio-transmission phenomena associated with the reflections of radio pulse and spark signals are outlined and a brief theoretical consideration of the form of index of refraction-variation best adapted to explain the observed phenomena given. The discussion considers the relation of this index of refraction-variation to that discussed in a previous paper and that recently considered by Breit. The results of long-wave field-strength observations are also presented. Evidence for a considerable diurnal layer-movement is found from the short-wave observations of layer-height.

Summary of progress in the study of radio wave-propagation phenomena. G. W. Kenrick and G. W. Pickard. Proc. Inst. Radio Eng., vol. 18, 649–668 (April 1930).

Recent progress in the study of radio wave-propagation phenomena is surveyed. The paper consists of three parts: (*A*) Historical review; (*B*) recent developments; and (*C*) conclusions and outlook. The Störmer-van der Pol echoes and their theoretical interpretation are discussed as are also magnetic and solar correlations. The need of further consistent observations and other means of investigation are emphasized.

List of publications of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, 1929. J. J. Kolar. Carnegie Inst. Wash., 11 pages (December 31, 1929).

This list contains titles of some 117 papers and contributions to scientific societies and magazines and of annual report published during the calendar year 1929 on magnetic, electric, and oceanographic results by members of the staff of the Department. It is in continuation of similar lists for publications during 1904 to 1927 and during 1928.

Principal magnetic storms recorded at the Huancayo Magnetic Observatory: March to April 1929; May to August 1929; October to December 1929; January to March 1930. P. G. Ledig. Terr. Mag., vol. 34, 262 (September 1929); 323–324 (December 1929); vol. 35, 53 (March 1930); 117 (June 1930).

Directions for observing magnetic inclination with a field earth-inductor.[1] H. E. McComb.

These directions are for the earth inductor and galvanometer of the C. I. W. design and type now extensively used in the field. Detailed descriptions of details of the two instruments with notes on adjustments and tests are followed by extended directions for operation.

Low-frequency radio transmission. P. A. de Mars, G. W. Kenrick, and G. W. Pickard.

This paper presents the results of field-intensity measurements on low-frequency transmission from station WCI of the Radio Corporation of America located at Tuckerton, New Jersey. The results of observations made at Newton Centre and Medford, Massachusetts, are presented. Apparatus for alternating antenna-observations with variously oriented loop-observations is described and the results of such measurements given. The relation of the state of elliptical polarization of received signals to loop-responses for various positions of the loop is investigated theoretically and the results thus obtained applied to an interpretation of the observations. The necessary approximations required to render this problem determinate are pointed out and their questionable validity emphasized. A mean of received signal-intensity in the absence of magnetic disturbances is presented which shows it to be lowest during the night with strong sunrise- and sunset-peaks. An inversion of received signal-intensity is noted during magnetic-storm conditions. At such times the night field-strength exceeds the day values.

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[1] Prepared cooperatively by the United States Coast and Geodetic Survey and the Department of Terrestrial Magnetism.

The distribution of oxygen in the Pacific Ocean between California and the Hawaiian Islands.[1] E. G. Moberg, J. P. Ault, and H. W. Graham.

This paper presented the preliminary discussion of the oxygen-content data obtained by the *Carnegie* on the passage from San Francisco to Hawaii in September 1929, and the results justify the following conclusions for the area investigated: (1) At the surface the water is nearly saturated with oxygen which consequently varies inversely as the temperature; (2) the oxygen-content is high but variable in a layer of water extending from the surface to a maximum depth of 400 meters and in the upper part of this layer occur the maximum oxygen-values which are caused by photo-synthesis; (3) below 400 meters the oxygen-content decreases with depth and reaches a minimum of from about 0.2 to 0.9 ml. per liter at 700 meters; (4) below 700 meters the oxygen-content increases slowly with depth but never attains the same concentration as at the surface; (5) except near the surface, the oxygen-content increases with distance from the mainland—probably because of differences in the circulation and in the biological conditions; (6) the minimum oxygen-content is lower than at corresponding latitudes in the Atlantic, and below 700 meters the oxygen-content is lower than in any part of the Atlantic in corresponding depths; (7) the relatively low oxygen-content of the deep-water suggests that this water has been removed from contact with the atmosphere for a long period of time.

The distribution of oxygen in the Pacific as an index of the circulation of the water. E. G. Moberg and H. W. Graham. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Oceanogr., August 1930, 95-97 (June 1930).

This is a brief preliminary summary of the investigation of the oxygen-content data obtained on the *Carnegie* from San Francisco to Honolulu to Pago Pago during September to November 1929. The conclusions confirm those given in the preceding paper. The results show that the water below 2000 meters contains an appreciably greater quantity of oxygen in the South Pacific than at corresponding latitudes in the North Pacific. This indicates that the deep-water flows in a northerly direction and this possibility is corroborated by the fact that south of the equator the oxygen-content at lower levels increased with increasing latitude. However, in the North Pacific the oxygen-content below 2000 meters remained practically constant from the equator to latitude 37°, and from this it appears improbable that appreciable quantities of water flow north across the equator in the region where the observations were made.

Since no oxygen-data are available for the western half of the North Pacific nor for almost all of the South Pacific, it is not possible to draw any definite conclusions, but the information at hand suggests that no large quantities of water enter the North Pacific from the south, at least not in its eastern part, and that the subsurface-currents in the South Pacific are of a different nature and apparently distinct from those in the North Pacific. The data indicate, further, that deep-water enters the Pacific from a southerly direction but, because of the difference in the oxygen-content between corresponding areas in the south latitudes of the Pacific and of the Atlantic, it appears highly improbable that antarctic or subantarctic water is supplied to the north central part of the South Pacific by a direct route and in an unmixed condition.

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[1] Presented at the meeting of the Western Society of Naturalists, Pacific Grove, December 1929.

The phosphate-content of the surface-water in the Pacific as related to the circulation. E. G. Moberg, H. R. Seiwell, H. W. Graham, and J. H. Paul. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Oceanogr., August 1930, 98–100 (June 1930).

This communication gives the preliminary results of the discussion of data for phosphate-content obtained on the *Carnegie* in the Pacific during October 1928 to November 1929 as related to the circulation. Fairly large quantities of phosphate were obtained as far south as San Francisco—probably due to water from the Bering Sea being mixed with the California Current, but at the stations near the coast probably also to upwelling of deep-water. South of latitude 10° north, the phosphate-content was nearly everywhere considerably higher than in most regions north of this latitude. The largest quantities were observed near the Peruvian coast where large volumes of deep-water are known to reach the surface. Information concerning the surface-currents in the South Pacific is less complete than for the North Pacific. The possibility that phosphate in appreciable quantities is carried to any great distance from the South American coast is contradicted by the fact that the average phosphate-content did not decrease noticeably with distance from the coast. The marked variability in the quantity of phosphate between stations located in this region indicates that the rate at which prosphate is supplied is also variable. Such a condition would result from vertical currents and the phosphate-content suggests that such currents exist in the part of the South Pacific studied by the *Carnegie.*

The diurnal variation of the electric potential of the atmosphere over the oceans. W. C. Parkinson and O. W. Torreson. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., August 1930, 65–68 (June 30, 1930).

The recording apparatus and the records obtained with it over the entire period of the *Carnegie's* seventh cruise furnish the material for this paper. No observations with the eye-reading instrument are included. A brief history of the changes in location of the apparatus on the ship and of modifications in the collecting system is given, followed by description of the methods of controlling the operation of the apparatus to insure correct values of potential. In the latter section, insulation-tests, calibrations, reduction-factor determinations, meteorological notes, and the effect of the ship's operation and equipment are outlined. A table, giving for each month from August 1928 to November 1929 the number of days at sea, the days affected by various disturbing factors, and finally the number of days accepted as "normal," is shown. The 82 "normal" days, grouped into three-month seasonal groups, yield curves in remarkable agreement with those obtained on cruises IV, V, and VI, substantiating the previous conclusion that the atmospheric potential, when freed from local effects, varies in the same way and at the same time over the whole Earth. The results of harmonic analysis of the data from Cruise VII are compared with those from the data of cruises IV, V, and VI, and are found in excellent agreement.

Compass and dip-circle deviations caused by harmonic motion. W. J. Peters. Proc. Internat. Oceanogr. Congress, Seville, 135–146 (1929).

The abstract on pages 264–265 of the annual report for 1928–29 summarizes the experimental work and conclusions drawn in this communication.

Work of the *Carnegie* to date. W. J. Peters. Pub. Nation. Res. Council, Trans. Amer. Geophys. Union, 10th and 11th annual meetings, 101 (June 1930).

See page 265 of the annual report for 1928–29 for an abstract of this paper.

On the possibility of using available vessels for determining magnetic secular-variation.[1] Pub. Nation. Res. Council, Trans. Amer. Geophys. Union, 10th and 11th annual meetings, 197–200 (June 1930).

It is improbable that provision for a non-magnetic vessel to replace the *Carnegie* will be made in the near future. Although the magnetic distribution-survey of the oceans is practically completed, additional secular-variation data at stations 1000 to 1500 miles apart over the sea are quite necessary. This paper considers the minimum requirements as regards non-magnetic construction in any vessel, which may be built for other scientific researches, to obtain magnetic observations of requisite accuracy for the study of secular variations.

Investigation of some individual changes in magnetic elements during a magnetic storm. W. J. Peters. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., August 1930, 51–55 (June 30, 1930).

There is a striking general similarity in the magnetograms of a magnetic storm obtained at different observatories. Individual changes in the traces, however, vary over the globe and the uncertainty of identifying any particular feature of a magnetogram as being the corresponding feature of the magnetogram of some other observatory has already been discussed in the investigation of the time of propagation of magnetic storms over the Earth's surface.[2]

The present investigation was undertaken on the suggestion that the directions and even the amplitudes of individual rapid changes occurring at the beginning (sudden commencements) or during a storm might yield more unimpeachable data for an investigation, since in this case accuracy as regards time is required only in time-differences, and absolute time is referred to one meridian merely to identify the beginning by cognizance of the hour and nearest tenth. There is also the possibility that significant correlations might be revealed by markedly individual changes that could be masked in using hourly means.

The paper gives the results of the studies made for the storm beginning about $2^{h}.2$ G. M. T. September 21, 1925, from the magnetograms of twenty-five observatories as follows: Sodankylä, Pavlovsk, Sitka, Swerdlovsk (Katharinenburg), Potsdam (Seddin), De Bilt, Karsani, Cheltenham, Tucson, Dehra Dun, Helwan, Honolulu, Teoloyucan, Alibag, Antipolo, Batavia,

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[1] Presented at the meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, May 2, 1930.

[2] Terr. Mag., vol. 30, 49–50, 1925; also C. Chree, British (*Terra Nova*) Antarctic Expedition 1910–13, 204, 1921.

Apia, Huancayo, Mauritius, Vassouras, Watheroo, Pilar, Toolangi, Christchurch, and Orcadas. The investigation related to differences between the value of the respective element immediately before the commencement, which in this case is fairly constant, and the values at four subsequent instants, namely: (*a*) At the first crest, trough, or pause in the rapid motion occurring within one minute of the beginning of the motion; (*b*) the crest, trough, or pause occurring three minutes after the beginning; (*c*) the same at fifteen minutes; and (*d*) the same at twenty-five minutes. No account was taken of the difference in diurnal variation for these intervals, as it would scarcely affect any but the 25-minute interval.

So far as the work has gone the conclusion is drawn that, if the interpretations of the traces are strictly according to definition and the origin of the disturbance is cosmical, then local conditions alter its final effects at the respective observatories.

Comments on Agenda for the Prague Assembly: Radio Laboratory, Newton Centre, Massachusetts. G. W. Pickard. Trans. Prague Meeting, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., September 1927. Bull. No. 7, 202–203 (June 1929).

The use of resistivity-measurements in the detection of mineralized areas. W. J. Rooney. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., August 1930, 74–75 (June 30, 1930).

A brief discussion is given of the possibility of detecting the presence and location of certain types of concealed geological discontinuities by surface-measurements of earth-resistivity using the C. I. W. earth-resistivity meter. This discussion is based upon observations during 1928 in cooperation with the United States Bureau of Mines at three sites containing mineralized areas. At the first station the changes in values of earth-resistivity appear to be due chiefly to variations in the conductivity of the serpentine and dependent on the amount of local alteration the rock had undergone. At the second site—a well-drilled region over a magnetite mine—the results gave a good indication of the depth, thickness, and dip of the ore-body. At the third site—another well-drilled region containing magnetite with very non-uniform overburden—the agreement of earth-resistivity results with those of drill-tests was 50 per cent. For a more detailed summary of this report see annual report for 1928–29, page 266.

Earth-resistivity survey at Huancayo, Peru, and relation of resistivity to earth-current potential records.[1] W. J. Rooney.

Earth-resistivity survey at Huancayo, Peru. W. J. Rooney and O. H. Gish. Terr. Mag., vol. 35, 61–72 (June 1930).

This survey, carried out near the Huancayo (Peru) Magnetic Observatory in the high Andes, is one of a series of earth-resistivity surveys made in connection with the study of earth-currents at observatories where potential-gradient registration is in progress. The general resistivity of the region and its variation with position, depth, direction of current-flow, and rainfall were determined. All may affect potential records and are indicative of the geological structure.

The resistivity of soil near the surface varied from over 100,000 to less than 2000 ohm-cm., depending on the character of the overburden. The mean values tended to converge to a value around 10.000 ohm-cm. as earth to depths of 200 to 300 meters was included in the measurements. These results are typical for an underlying structure of sedimentary rocks. A local area of high resistivity (values three times the mean for the region as a whole) was found near one earth-current line and explains the high potential-gradient records obtained from that line. The results were found to be independent of the orientation of the survey-lines, indicating that the region is laterally isotropic. The seasonal variation was small and relatively unimportant.

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[1] Presented before the Philosophical Society of Washington, March 15, 1930.

Results from radio observations on the *Carnegie*, May 1928 to November 1929. S. L. Seaton.

This report with the radio log for Cruise VII of the *Carnegie* summarizes the wireless work. Because of the great majority of communications from 19^h to 24^h ship's time over those during the rest of the day, any general conclusions, such as skip-distances at various frequencies, variations of signal-strength, etc., are impossible. While graphs of signal-intensity data are incomplete as regards distribution over the whole twenty-four hours, it appears that from about 6^h to 18^h the 6000-, 8000-, and 10,000-kilocycle signals did not come through well over great distances, that 12,000- and 14,000-kilocycle signals are weak during the same period but show maxima around sunrise and sunset, decreasing in intensity during the night, and that the 18,000- and 20,000-kilocycle signals are good generally all through the twenty-four hours (most of the last observations were made near the equator). Graphs of monthly mean signal-intensity against sun-spot-numbers show apparently phase-agreement by 180°. Transmission-behavior observed during sunrise and sunset periods was frequently extremely erratic. When 7,000-kilocycle signals faded at night over distances of 2,500 miles, those on 14,000 kilocycles usually became stronger.

Observations on phosphate-content and hydrogen-ion concentration of the North Sea, the southern entrance to the Norwegian Sea, and the water south of Iceland. H. R. Seiwell.

These results are from data obtained on the *Carnegie* between Hamburg, Germany, and Reykjavik, Iceland, in July 1928. The phosphate-content near the Shetland Islands increased to five or six milligrams (P_2O_5) per cubic meter—an enrichment possibility resulting from an influx of richer Atlantic water flowing to the south of the Shetlands. The content of surface-water between the Shetland and Faroe Islands was greatest at the east central and northeast part of the Faroe-Shetland Channel, and from the discussion it appears may be due chiefly to mixing of surface with deeper rich phosphate water resulting from vertical and horizontal vortex movements. The conditions on either side of the Faroe-Iceland Ridge are sharply contrasted, the salinities and temperatures to the south being very high compared with those north. In general the phosphate-content south of Iceland was highest where water is deep and farthest from shore.

In a general way the variation of surface hydrogen-ion concentration is coincident with differences in circulation existing in the region.

Earth-inductor measurements aboard the *Carnegie*, Cruise VII.[1] F. M. Soule. Terr. Mag., vol. 35, 103–109 (June 1930); Pub. Nation. Res. Council, Trans. Amer. Geophys. Union, 10th and 11th annual meetings, 202–206 (June 1930).

These communications describe the earth-inductor equipment used aboard the *Carnegie* during May 1928 to November 1929 for the determination of magnetic inclination and the experimental work using the same equipment for the determination of horizontal intensity. The potentiometer-method was superior to the current-method because it relied on standards of resistance and electromotive force embodied in the potentiometer and standard cell instead of standards of resistance and current embodied in the portable bridge and microammeter.

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[1] Presented at the meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, May 2, 1930.

Sonic depth-finding on the *Carnegie*, Cruise VII.[1] F. M. Soule and C. C. Ennis. Pub. Nation. Res. Council, Trans. Amer. Geophys. Union, 10th and 11th annual meetings, 264–274 (June 1930).

The instruments and methods used to determine depths aboard the *Carnegie* during May 1928 to November 1929 are described. A discussion of the accuracy is followed by accounts of the program and some of the difficulties encountered. Profiles of newly discovered features and irregularities of the bottom are shown. These, as well as the entire sounding-program of the vessel, stress the need of more thorough exploration of ocean-depths and impress one with the inadequacy of present knowledge on bottom-features.

On the present sunspot maximum and a correlation with radio reception. H. T. Stetson and G. W. Pickard. (Abstract) Pop. Astr., vol. 37, 388–390 (August-September 1929).

Program of the International Polar Year 1932–1933.[2] H. U. Sverdrup. Pub. Nation. Res. Council, Trans. Amer. Geophys. Union, 10th and 11th annual meetings, 183–187 (June 1930).

Some oceanographic results of the *Carnegie's* work in the Pacific—the Peruvian current.[1] H. U. Sverdrup. Pub. Nation. Res. Council, Trans. Amer. Geophys. Union, 10th and 11th annual meetings, 257–264 (June 1930).

On the basis of the observed temperatures and salinities of the waters west of Peru it was shown that the typical stratification of the Pacific easily could be recognized. Great local variations in temperature and salinity occur only above a level of about 400 meters. At a level of about 700 meters an intermediate current, carrying water of low salinity and subantarctic origin to lower latitudes, is found, and below a depth of about 1500 meters homogeneous deep-water is met with. The Peruvian current is a shallow current, reaching down to about 400 meters only and the cold water which wells up along the coast comes from depths smaller than 400 meters.

Some aspects of oceanography.[3] H. U. Sverdrup. Sci. Mon., vol. 31, 19–34 (July 1930).

The important part which the eddy-motion of the water plays in transferring kinetic energy, heat, and dissolved substances from one water-layer to another is emphasized, and it is shown that the development of the eddy-motion to a large extent depends upon the stratification of the water. Examples from the North Siberian Shelf (*Maud*), the oyster-basins of western Norway, and the Pacific Ocean (*Carnegie*) illustrate the intimate connection between the stratification of the water, the distribution of dissolved substances of gases, and the great variation in the conditions for the development of organisms.

The deep-water of the Pacific according to the observations of the *Carnegie*. H. U. Sverdrup. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Oceanogr., August 1930, 87–94 (June 30, 1930).

The observations of the *Carnegie* show that the water of the Pacific is remarkably uniform below a level of about 2000 meters. The salinity decreases very slowly from south to north, but the total range is only about

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[1] Presented at the meeting of the Section of Oceanography of the American Geophysical Union, Washington, May 1, 1930.

[2] Presented at the meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, May 2, 1930.

[3] Lecture delivered at the Carnegie Institution of Washington, April 8, 1930.

0.05 per mille. The highest temperatures are found under the Equator, disregarding the conditions in the Gulf of Panama. The total variation in temperature is about 0°2 C.

The origin of the deep-water of the Pacific Ocean as indicated by the oceanographic work of the *Carnegie*. H. U. Sverdrup. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Oceanogr., August 1930, 101-109 (June 30, 1930).

All the available data point strongly in the direction that water of the same type as the deep-water of the Pacific is formed in the eastern part of the Indian Antarctic Ocean and that the origin of the deep-water of the Pacific has to be sought there. This deep-water probably enters the Pacific through the opening south of New Zealand, but the inflow must be very slow and the entire deep-water circulation of the Pacific correspondingly slow.

The observations of the *Carnegie* are not extended over a sufficiently large area and do not reach deep enough at a sufficient number of stations to allow any definite conclusions as to the character of the deep-water circulation in the Pacific, but attention can be drawn to a few possibilities. Part of the deep-water may mix with the antarctic water and return along the continental shelf to the Indian Antarctic Ocean. Another part may mix with intermediate antarctic currents and return to the south at levels between 1000 and 2000 meters. Still another part may enter the northern Pacific where it at some places may be transported towards the surface in order to replace water which perhaps is carried from the Pacific Ocean to the northern parts of the Indian Ocean. It is also possible that the inflow of water in the northern Pacific is greater than the outflow, because evaporation may exceed precipitation.

If the preceding considerations are correct we must expect the deep-water of the Pacific to have a relatively low oxygen-content, because the circulation is slow and because the water has been formed by mixing of water-masses which already have traveled a long distance as deep-sea currents. This conclusion is confirmed by the oxygen-observations on board the *Carnegie* in accordance with the discussions of those data by Moberg and Graham (1930), which show that the oxygen-content of the deep-water in the Pacific is much lower than the content in corresponding depths in the Atlantic. At a depth of 2500 meters the quantity of oxygen in the Pacific waters between latitudes 35° north and 15° south varies from 1.8 to 3.2 ml. per liter as compared to values between 5 and 6 ml. per liter in corresponding depths and latitudes of the Atlantic.

The observations of the *Carnegie* combined with results of researches in other oceans thus furnish evidence as to the origin of the deep-water of the Pacific and the character of the deep-water circulation, but it must be emphasized that the above conclusions are based on very scanty information, especially from the Antarctic Ocean. An extensive exploration of the Antarctic Ocean is highly desirable in order to throw more light on the important questions dealing with the interoceanic exchange of water and the origin of the deep-water of the Pacific.

Basic concepts common to meteorology and oceanography.[1] H. U. Sverdrup.

The problems of geophysics are closely related to the problems of physics but the methods of attack are widely different. The physicist has full control over his experiments and can draw new conclusions from them by means of theoretical considerations. The geophysicist studies the complicated phenomena in nature and, when entering upon theoretical research, he has to introduce assumptions so simple that his results represent only the coarsest features of nature's experiments. Theoretical research in geophysics is, in spite of these difficulties, steadily advancing and several results have found practical application as, for example, in the computation of ocean-currents on the basis of observed temperatures and salinities.

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[1] Lecture delivered at the Massachusetts Institute of Technology, Cambridge, Massachusetts, May 23, 1930.

It is a fortunate feature that theoretical investigations within meteorology and oceanography have so much in common that often advance within one of these sciences has been followed by a similar advance within the other. Two examples illustrating the common concepts were given, one dealing with dynamic computations in the atmosphere and the sea and the other dealing with the influence of the eddy viscosity upon air- and sea-currents.

What the oceans mean to us. H. U. Sverdrup.

This was the subject of a radio address broadcast June 30, 1930, under the auspices of the Press Service of the American Association for the Advancement of Science from station WRC at Washington over the National Broadcasting Company's network. Particular reference was made to the geophysical work of the *Carnegie* at sea.

Upper-air currents at Honolulu, T. H. A. Thomson. Mon. Weath. Rev., vol. 56, 496–498 (December 1928).

Blue-sky measurements at Apia, Samoa. A. Thomson. Mon. Weath. Rev., vol. 56, 499 (December 1928).

Observations of upper-air currents at Apia, Western Samoa: Second series. A. Thomson. Wellington, W. A. Skinner, Govt. Printer, 79 pages (1929).

This monograph gives the upper-air data based on 239 pilot-balloon flights made at the Apia Observatory from February 1925 to December 1928.

Abnormal vertical air-currents. A. Thomson. Met. Mag., vol. 65, 65 (April 1930).

An apparatus for presenting animated curves or graphs. O. W. Torreson.

This apparatus, as originally constructed, consists of two sets of drums so arranged within a wooden cabinet that endless bands may be placed on each pair and the bands made to move in a horizontal direction across a vertical slit in the face of the cabinet by rotating the drums with a small motor. The bands are made of two layers of material, the under layer being of some strong, inelastic, transparent material such as tracing cloth, and the outer of black, opaque paper. The details of the curve or graph to be presented are cut from the paper layer and, when the band is passed across the slit and illuminated from the rear, the effect produced is that of a bright spot moving up or down in the slit. Along the side of the slit, on the face of the cabinet, is placed a suitable scale to represent the vertical coordinate of the curve. Along the top of the band are placed suitable figures representing the horizontal coordinate, seen through an aperture above the top of the slit. Any desired number of curves may be displayed simultaneously by increasing the number of pairs of drums, and comparison of different curves which may have important bearing upon one another is greatly facilitated by this apparatus. It is especially helpful toward securing the interest of, and presenting information to, those unaccustomed to interpreting printed curves or graphs.

On the use of systematic explanatory remarks or legends in connection with the tabulation of atmospheric-electric data. O. W. Torreson.

The paper is devoted to a summary of the symbols or legends in use up to the present at each of the observatories of the Department of Terrestrial

Magnetism. The requirements for a standard system of symbols or legends include applicability to all atmospheric-electric instruments, applicability to published tabulations without alteration, and conformity with legends and symbols applied to magnetic tabulations. A table meeting these requirements as nearly as possible is given.

Multiple coincidences of Geiger-Müller tube-counters. M. A. Tuve. Phys. Rev., vol. 35, 651-652 (March 15, 1930).

The new possibilities which arise in the study of very penetrating beta-particles ("cosmic rays") when the coincidences are observed between three or more Geiger-Müller tube-counters (elektronen zahlröhre) are pointed out. The first two counters serve as a slit system, picking out a beam, which is deflected by a magnetic field or a scattering block or otherwise subjected to experimental conditions, and the third counter, which is movable, serves to locate the direction of deflection of the particles. The requirement of multiple coincidences also serves to reduce the "accidental" coincidences below any desired figure, for obvious statistical reasons. A brief oscillographic study was made of the circuits of the automatic coincidence recording circuit which was developed for this work. Records are being made by this method of the amount of penetrating radiation received from a narrow band of the sky, searching for a possible variation in intensity with stellar time.

Echo-sounding of the Kennelly-Heaviside layer. M. A. Tuve. Pub. Nation. Res. Council, Trans. Amer. Geophys. Union, 10th and 11th annual meetings, 78-79 (June 1930).

An abstract of this paper is given on pages 267-268 of the annual report for 1928-29.

Note on investigation of electrical conditions in the upper atmosphere. M. A. Tuve. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., August 1930, 73 (June 30, 1930).

The application of high potentials to vacuum-tubes. M. A. Tuve, G. Breit, and L. R. Hafstad. Phys. Rev., vol. 35, 66-71 (January 1, 1930).

A brief progress-report is made on the results so far obtained in the development of vacuum-tubes to which the very high voltages produced by Tesla coils (greater than 10^6 volts) can be applied. One cascade tube has been constructed which withstood repeatedly a voltage of 1,400,000 volts, and others have been used at lower voltages. This method, originally developed by Coolidge, gives promise of being suitable for voltages of several million, and eventually perhaps even higher. No effort has been made so far to use these tubes with a definite and controlled emission, since experience has shown that single-section tubes operated at several hundred kilovolts have approximately the same voltage-limitation with or without hot cathodes. The chief difficulty with very high-voltage tubes is that of preventing the uncontrollable (cold-cathode) emission which limits the voltage which can be applied. An electrodeless tube which withstood 1,000,000 volts is briefly described.

High-voltage tubes. M. A. Tuve, L. R. Hafstad, and O. Dahl. Phys. Rev., vol. 35, 1406-1407 (June 1, 1930).

It has been found that the internal shattering and puncturing of Pyrex high-voltage tubes is completely eliminated if the glass is "heat-worked" throughout, blowing out and contracting again at all points of the glass as in making a glass seal or joint. One such tube of 14 sections, 135 cm. overall, was operated up to 1950 kilovolts using the Tesla coil on single sparks.

Another has been used, *with one end grounded,* at 1900 kilovolts on single sparks, and at 1600 kilovolts using 120 sparks per second. A compact arrangement is described in which the tube is mounted inside of the high-voltage coil, with the electrodes connected to taps on the coil winding.

Diurnal variation of the atmospheric potential-gradient at Penalosa, Kansas. G. R. Wait. Terr. Mag., vol. 35, 137-144 (September 1930).

Atmospheric potential-gradient data from only a small number of American stations have been published. At but four of these was the character of the observations such as to furnish a diurnal-variation series. Three of the stations were either on or near the Atlantic coast while the remaining station was near the Pacific coast. There exists no published diurnal-variation series from a station situated well in the interior of the Continent. Such a station was consequently established at Penalosa, Kansas, near the geographical center of the United States and records of the potential gradient secured during a portion of August 1929.

Diurnal-variation results for the potential gradient at some land stations in the past may appear to have been seriously affected by a systematic variation and especially in the two factors, insulation-leak and atmospheric pollution. Considerable care was exercised, therefore, both before and throughout the series, to insure these factors would be negligibly small in the present investigation. The resulting diurnal-variation curve when plotted on Greenwich meridian time shows very close agreement with one obtained by the *Carnegie* over the Pacific Ocean the following month as well as with the one for the period August to October from data obtained on cruises IV, V, and VI of the *Carnegie.*

On need of measurements of dust-content in the study of atmospheric-electric phenomena. G. R. Wait. Trans. Prague Meeting, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., September 1927. Bull. No. 7, 242-243 (June 1929).

Note on the establishment of observatories for the measurement of atmospheric electricity. G. R. Wait. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., August 1930, 70 (June 30, 1930).

Aitken condensation-nuclei and atmospheric potential-gradient at Washington, D. C. G. R. Wait. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., August 1930, 72 (June 30, 1930).

The results of this discussion of data obtained at Washington of condensation-nuclei and atmospheric potential-gradient, utilizing also data obtained over the oceans, are summarized as follows: (1) The computed amplitudes of the 24-, 12-, and 8-hour waves in the diurnal variation of the atmospheric potential-gradient, when freed from the effect of atmospheric pollution, are approximately 77 per cent; (2) a change of one and one-half volts per meter in the potential gradient corresponds approximately to a change of 1000 nuclei per cubic centimeter (the diurnal variation in condensation-nuclei from four 24-hour series varies from 7200 to 25,000 particles per cubic centimeter, which would correspond to a change in potential gradient of about 27 volts per meter); (3) an increase in potential gradient corresponds to an increase in the number of nuclei per cubic centimeter, agreeing in this respect with observations made at Watheroo.

Rapid fluctuations in air-potential at Watheroo as shown by the daily electrograms. G. R. Wait.

The daily record of the atmospheric potential-gradient at Watheroo generally shows rapid fluctuations, the amplitudes of which are greater during the daylight portion of the 24 hours than at night. The diurnal variation in amplitude of the fluctuations corresponds rather closely to the diurnal variation in temperature of the outside air as recorded by the thermograph. It is also very similar in character to the diurnal variation in wind-velocity as well as to the diurnal variation in amplitude of fluctuations in wind-velocity at this station. Curves representing the diurnal variation in amplitude of fluctuations in potential gradient have been drawn for December 1925, June 1926, and December 1927. In 1925 and in 1926 the recording was by means of a bifilar electrometer, while in December 1927 the bifilar electrometer had been replaced by a quadrant-electrometer. All three curves begin shortly after sunrise a rapid increase from a broad flat minimum, sinking again to the broad flat minimum shortly after sundown. The range in fluctuations of the potential gradient was from 12 to 14 volts per meter over the minimum and from 26 to 28 volts per meter over the maximum part of the diurnal-variation curve.

From the data for June 1927, correlation-coefficients between the diurnal variation in the range of fluctuation in the potential gradient and the following elements were determined as follows: (*a*) Wind-velocity, 0.99; (*b*) range in fluctuation of the wind-velocity, 0.98; (*c*) reciprocal of the relative humidity as recorded with the hygrograph, 0.89; (*d*) temperature as recorded with the thermograph, 0.88. Thus the diurnal variation in the range of fluctuations in potential gradient corresponds almost exactly to the diurnal-variation curves of wind-velocity and also of the range in fluctuations of the wind-velocity.

Grouping of the values of the range in fluctuations of potential gradient according to different wind-velocities indicated increase of the former element with increase of wind-velocity to about 9 miles per hour, after which it remained approximately constant. Grouped in this manner, the range in fluctuations in potential gradient during December 1925 and June 1926 (while the bifilar electrometer was in use) averaged about 12 per cent higher than during December 1927 (while the quadrant-electrometer was in use). It is significant that, when the quadrant-electrometer replaced the bifilar electrometer, the capacity of the whole collector-system was thereby increased by about 12 per cent.

Preliminary values of the atmospheric-electric elements at Tucson, Arizona. G. R. Wait.

The average value of the potential gradient during the last few days of September 1929 at Tucson, Arizona, was about 50 volts per meter. The maximum occurred not far from noon and was about 80 volts per meter, and only a little above 20 volts per meter at the time of minimum.

The average value of the positive air-earth current during 5 days in October 1929 was only slightly greater than 3×10^{-7} E.S.U., the maximum reaching 5×10^{-7} E.S.U. some time during the late forenoon; the minimum value was about 2×10^{-7} E.S.U.

The average value of the positive conductivity of the atmosphere was about 3.0×10^{-4} E.S.U. for 12 days during October 1929. The maximum value was slightly greater than 4.0×10^{-4} E.S.U. and occurred about sunrise; the minimum was slightly greater than 2.0×10^{-4} E.S.U. and occurred shortly before sunset. The corresponding average values of the negative conductivity for 7 days during October 1929 were about 2.5, 3.0, and 1.7, all in 10^{-4} E.S.U., the times of maximum and minimum being practically the same as in the case of the positive conductivity.

The ratio of the positive to the negative conductivity of the atmosphere during five days in the latter part of October 1929 underwent a similar systematic diurnal-variation, with times of occurrence of maximum and minimum as for the positive air-earth current. The maximum value for the ratio was about 1.3 and the minimum value about 1.05.

Relationship between the number of Aitken nuclei per cubic centimeter and the limit of visibility. G. R. Wait.

Wigand[1] has suggested an equation of the form, $DV = a(e_s - e)^{2/3}$, where D is the number of Aitken nuclei per cubic centimeter, V is the limit of visibility, e_s is the vapor-pressure of saturated air, e is the actual vapor-pressure, and a is a constant, to express the relationship between the number of Aitken nuclei and the limit of visibility. The equation $V(AR + D) = K$ (see annual report for 1928–29, p. 269), where R is the relative humidity expressed in per cent and A and K are constants, seems to express well this relationship from data taken at the Watheroo Magnetic Observatory and over the oceans aboard the *Carnegie*. Both equations have been applied to the Watheroo data. The average difference between each calculated value of $(1/a)$ and the mean of all is about 70 per cent of the mean, while the average difference between each calculated value of K and the mean calculated value is about 31 per cent of the mean.

Diurnal variation in the ratio of positive to negative conductivity. G. R. Wait.

A preliminary investigation into the ratio of the positive to the negative conductivity for Watheroo, for Huancayo, and for Tucson shows curves similar in character in each case to those of potential gradient and air-earth current. When plotted on Greenwich meridian time, the curves from all three stations are similar in character, thus indicating that this ratio progresses during the 24 hours according to universal time. The average daily maximum value was about 30 per cent higher than the average daily minimum value at each of the three stations.

Diurnal variation in the number of condensation-nuclei at Washington, D. C. G. R. Wait, K. L. Sherman, and O. W. Torreson.

Diurnal-variation observations on the number of condensation-nuclei made by means of an Aitken pocket-counter of the usual type at Washington during March 27–28, 1930, show a diurnal-variation curve similar in character to that for the mean of three previous diurnal-variation series during the month of March in 1927 and 1928. The general features of the mean diurnal-variation curve for the four days fall into three distinct groups, namely, (1) a low flat minimum extending from 0^h to 6^h, 75° meridian mean time, with the average number of particles per cubic centimeter about 9000, (2) three hourly values of rapidly increasing number of particles, and (3) a long flat maximum when the number of particles was more or less constant at an average of about 21,000 per cubic centimeter. The average number of particles per cubic centimeter during the entire 24 hours was about 17,000. A small depression, several hours in extent, occurred early in the afternoon on each of the days when diurnal-variation observations were made, the depression centering on about 15^h in the mean curve.

A comparison of magnetic disturbances at different stations.[2] W. F. Wallis. Terr. Mag., vol. 35, 93–101 (June 1930); (abstract) J. Wash. Acad. Sci., vol. 20, 138 (April 4, 1930).

A brief discussion of the magnetic records obtained during the MacMillan Baffin Island Expedition of 1921–22 is given with comparison of results from several other well-distributed observatories. For comparison a short-well-defined, world-wide magnetic storm (March 14, 1922) was selected, and departures from normal values were compiled and compared by three methods: (1) Difference between the disturbed and normal total-intensity vectors; (2) excess energy of the magnetic field due to the disturbance; (3) magnetic activity proposed by Chree, using absolute daily ranges in three rectangular components of the total magnetic intensity. It is concluded that the geographic distribution of magnetic activity during disturbance bears a close relation to the auroral zone, and there is evidence that the zone of maximum auroral frequency is also a zone of maximum magnetic activity. If we take average values of the disturbance-vectors over several months, there is a marked regularity in their directions for the individual stations, and for all stations the general direction of the horizontal-intensity disturbance-vectors is southward. This indicates that the disturbing currents in the upper atmosphere flow in general from east to west around the Earth.

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[1] Ann. Physik, vol. 59, 729 (1919).

[2] Presented before the Philosophical Society of Washington, February 1, 1930.

The geographical distribution of magnetic disturbance. W. F. Wallis. Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Terr. Mag. and Electr., August 1930, 56–57 (June 30, 1930).

A similar method to that used in the preceding investigation was followed in a study of the magnetic storm of January 29, 1924, as recorded at Refuge Harbor and nine other observatories. This storm began suddenly and continued for twenty-six hours. The average hourly change in the total-intensity vector, the average excess energy of the magnetic field, and the curve of auroral frequency were plotted in relation to the magnetic latitude. The three curves show a resemblance in their main features and are strikingly similar to those obtained for the magnetic storm of March 14, 1922. The conclusions reached in the former case are, therefore, confirmed.

A comparison of the average intensities of the two storms at the different stations shows that at some stations the second storm was more intense than the first, while at other stations the reverse was true, but the average of seven stations indicates that the second storm was 9 per cent more intense than the first. Local influences, not yet understood, play a large part in determining the character of the disturbance at any particular spot on the Earth's surface.

Electrical conductivity-method for determination of salinity aboard ship.[1] F. Wenner, E. H. Smith, and F. M. Soule. Pub. Nation. Res. Council, Trans. Amer. Geophys. Union, 10th and 11th annual meetings, 299–300 (June 1930).

Apparatus for the determination aboard ship of the salinity of sea-water by the electrical conductivity-method.[2] F. Wenner, E. H. Smith, and F. M. Soule. Dept. Comm., Bur. Stan. J. Res., vol. 5, 711–733 (September 1930); (abstract) Rep. and Comm., Stockholm Assembly, Internat. Geod. and Geophys. Union, Sec. Oceanogr., August 1930, 110–111 (June 30, 1930).

These two papers describe in detail the design, construction, and development of three salinity-instruments using the electrical conductivity-method to determine salinity of sea-water on vessels of the United States Ice-Patrol Service and on the *Carnegie*. The theory of the instrument is given, and also the precision of results obtained shown by comparisons aboard ship with titrated water. (The complete paper will be published in the fall of 1930 in the Bureau of Standards Journal of Research.)

[1] Presented at the meeting of the Section of Oceanography of the American Geophysical Union, Washington, May 2, 1930.

[2] Presented at Bureau of Standards meeting, Washington, April 15, 1930.

Directional recording of atmospherics at Watheroo Magnetic Observatory. F. W. Wood. Proc. Conference of Australian Physicists, Mathematicians, and Astronomers at Melbourne in August 1929, pp. 51–52.

The paper is a progress-report dealing with the records so far obtained at Watheroo from the atmospherics recorder loaned by the Australian Council for Scientific and Industrial Research. The instrument, which is after the design of Watson-Watt, is described and the records discussed. It is hoped that a second instrument will be installed in the near future at a distance of several hundred miles from the existing instrument, thereby eliminating the usual radio-goniometric ambiguity.

TORTUGAS LABORATORY[1]

In accordance with authorization by the Trustees of the Institution, investigations were continued at the Tortugas Laboratory during the summer of 1930. Upon invitation, Dr. Wm. H. Longley served as Executive Officer during the season. Mr. John W. Mills, chief engineer, remained in charge of all equipment. A large number of institutions were represented by investigators, and studies undertaken ranged from pure taxonomy to applications of physics and chemistry to physiological problems. Certain new studies were inaugurated, and important advances were made in a number of researches continued from previous years.

The following investigators studied at the Laboratory during the season:

W. E. Bullington. Randolph-Macon College. Structure, distribution and locomotion in Ciliates. July 9 to August 18.
L. R. Cary. Princeton University. Studies on Miracidia and Alcyonaria; Ecological changes on the Tortugas Reef since 1910. July 9 to August 4.
P. S. Conger. Carnegie Institution of Washington. Diatom Research. May 28 to June 9.
Haldane Gee. Scripps Institution of Oceanography, University of California. Influence of bacteria on calcium equilibrium. June 25 to August 18.
J. N. Gowanlock. Dalhousie University. Ecology and physiology of an earthworm of the intertidal zone. May 28 to August 18.
Caswell Grave. Washington University. Ascidian metamorphosis. June 25 to August 4.
D. L. Hopkins. Duke University. Physiology of marine amœbæ. June 11 to August 18.
W. H. Longley. Goucher College. Distribution and behavior of fishes. May 28 to August 18.
W. H. Longley jr. Acadia University. Assistant. May 28 to August 18.
H. W. Manter. University of Nebraska. Taxonomy and distribution of trematodes of fishes. June 25 to August 18.
Gordon Marsh. University of Texas. Bioelectric currents in *Valonia*. July 23 to August 18.
A. A. Schaeffer. University of Kansas. Mechanics of spiral movement in *Trichamœba*. June 11 to July 7.
Waldo L. Schmitt. U. S. National Museum. Decapod crustacean fauna of Tortugas. July 9 to August 18.
J. P. Visscher. Western Reserve University. Distribution of barnacles with special reference to behavior of Larvæ. July 9 to August 18.
Shigeo Yamanouchi. University of Tokyo. Physiological life histories of algæ. June 11 to July 21.

Characteristics, Taxonomy and Distribution of the Ciliates of Tortugas,
by W. E. Bullington

I had hoped, on going to Tortugas, to be able to complete a study of spiraling of the ciliates, *Frontonia*, *Stentor* and *Coleps*, together with a revision of their morphology and taxonomy, which had been begun elsewhere. However, after arrival, I found so many new forms and so few old ones that this hope was only partially realized.

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[1] Situated at Tortugas, Florida.

The large number of undescribed species in this region is very striking. Only a few of those seen during the summer have been found elsewhere. Those already seen included two of *Frontonia*, two of *Trachelocerca* and three of *Euplotes*. The new ones included one *Stentor*, three of *Coleps*, two of *Frontonia*, one *Trachelocerca*, one *Peritromus*, one *Holophryan* (genus not known), two of *Condylostoma*, etc.

A more or less complete study of spiraling and morphology was made of one *Stentor*, four species of *Frontonia*, three of *Coleps* and one *Peritromus*, and a less complete one of one *Trachelocerca*, two species of *Condylostoma*, several of *Strombidia*, etc. Under general morphology was included a study of body form, a comparison of a large number of individuals for size relationships, chief characteristics and an exact drawing to scale. Under spiraling was included a study of its direction, whether constant in the same species or varying and why, a comparison of left spiraling with right, study of size of spiral and speed of swimming under varying conditions.

A very striking characteristic of these ciliates is their beautiful coloration in which reds and yellows seemed to predominate, *e.g.*, red stentors, yellow and pink Condylostomas, red and yellow Hypotrichs, red Holophrya, etc.

In point of distribution, the various species seemed also to be confined more or less to particular areas and were in general found in no other. From Loggerhead Key came two species of *Coleps*—one from the coral rocks on the east side of the island, the other from the bottom of a tidal pool at the west end of the island. From Garden Key came one *Stentor*, one *Coleps* and one *Frontonia* (undescribed but previously seen at Cold Spring Harbor and Woods Hole). From Long Key came several species of *Strombidia* (unidentified), two of *Frontonia*—one new and the other undescribed but previously seen at Cold Spring Harbor and Woods Hole, and two of *Condylostoma*, new. From East Key came one new *Frontonia*.

Moreover, unlike the ciliates of the tidal pools and brackish marsh pools at Cold Spring Harbor and Woods Hole, the Tortugas ciliates were found not at the surface on broken up seaweeds but below the surface on algæ and on the bottom on sand, rocks and fragments of turtle grass. The higher temperatures of the surface waters so characteristic of this region probably account for this depth distribution.

Many other ciliates not listed above were seen, but time did not permit their study. This must await a later date.

SPIRALING IN THE PALOLO WORMS

Alfred G. Mayor (1905), while studying the swarming palolo worms (*Eunice fucata*) at Tortugas, observed that they swam with the posterior end in front and twisted in the direction of the hands of a clock—a right-hand spiral.

This past summer (1930), I had the privilege of observing these swarming palolos for the first time. The main swarm occurred on the morning of July 16 and I watched it from the time there was sufficient light to see, until the sun was half an hour or more high, when practically all of them had gone to pieces. During this time each of the thousands of individual worms (reproductive portions) observed in all this seething, squirming mass was swimming in short, wide spirals to the right and moving in a general westerly direction. Not a single worm was seen spiraling to the left. This confirms Mayor's observations of 1905.

But when the small, spherical, ciliated embryos, developed from eggs collected at the time of swarming by Doctors Cary and Visscher and fertilized in the laboratory with sperm cells collected at the same time and place, were studied twenty-four hours later, their spiral was found to be not to the right alone, like the reproductive segments of the mature worms. These embryos swam in both directions. When first observed, most of them were swimming in right spirals; only a few in left spirals. But as the embryos became older, more and more of them began spiraling to the left. The right spirals, however, were mostly, although not entirely, produced in spinning movements, with very little forward progression. Those embryos swimming most rapidly were spiraling to the left. Five of the right-spiraling individuals were found moving with sufficient forward progression to permit measuring the spiral. Sixty-nine complete spirals in these five, measured from 281μ to 1075μ in length, with an average of 655μ in length by 430μ in width. These spirals were short and wide, and were executed at a very slow rate of speed—too slow—and in segments too short to be measured.

Left spirals, on the other hand, measured in length, in 46 observations covering more than 200 complete spirals, from 578μ to 6933μ. They averaged 2136μ in length, or more than three times that of right spirals, and swam at a speed ranging from 1209μ to 5200μ per second, with an average, in 30 observations, of 2101μ per second.

Report on Investigations at Tortugas, by L. R. Cary

STUDIES ON MIRACIDIA

In an attempt to secure *Miracidia* in large numbers for an experimental study of Trematode development, adult worms from numerous hosts were obtained. Nearly all those obtained from Tortugas fishes had very few eggs far enough advanced in development to allow active larvæ to be obtained. In many species the oldest eggs in the distal portion of the uterus of fully grown worms were in an early stage of development, so that the later stages in the formation of the embryos must take place after the eggs are laid.

In the few instances where thin-shelled eggs are produced, which seems always to be associated with the complete development of the embryo before the eggs are laid, such a small number of mature eggs was obtained from any adult that any extensive experimental work was impossible.

The Trematode *Pleisiorchus cimbiformis* (R) from the urinary bladder of the Loggerhead turtle (*Caretta caretta*) (L) contained a large number of eggs from which larvæ could be obtained by simply crushing the adult worms. These *Miracidia* were, when active, 70μ in length by 31.5μ in diameter, and of a regular ellipsoid shape. The outer covering of the body consisted of 12 large ectoderm cells arranged in three rows. The cilia were long and robust. In striking contrast to what might have been expected from these structures, locomotion was relatively slow at all times.

One other species of Trematode from the intestine of a Frigate bird offered an abundant source of *Miracidia*, but since neither of these hosts could be obtained as a dependable source of supply, experimental work of this sort must await a more extensive survey of the available Trematode fauna.

Breeding Habits of Alcyonaria

It had previously been recorded that certain of the Gorgoniaceæ occurring on the reefs about Tortugas set free their eggs (*Plexaura flexuosa, Psuedoplexaura crassa*) *or* planulæ (*Briareum asbestinum*), in one, or several, large "swarms."

This year on the day (July 15) before the annual swarming of the Atlantic palolo worm, great numbers of Alcyonarian eggs were observed in the water at early morning. So abundant were the eggs, that over large areas the surface of the water showed pinkish streaks where they had been gathered into windrows by either wind or current action. At this time there was clearly marked about the shores of Loggerhead Key or when rowing over the reef, a strong odor characteristic of the tissues of practically all the "gorgonians." This appeared to be due rather to the presence of a mucous material set free at the time of egg-laying rather than to the fertilized eggs themselves.

About noon the embryos taken in abundance by a tow net were all in the form of morulæ, with the surface so rough that the thin, high ridges and relative broad depressions over the surface gave the whole structure a honeycomb-like appearance. By evening the larvæ had acquired the slender shape and active cilia of typical anthozoan planulæ.

For a period of ten days, some of these embryos were kept in glass dishes in which the water was changed twice a day. At the end of this time, tentacle buds were beginning to be recognizable and locomotion was becoming very sluggish. The larvæ would remain for relatively long periods quiescent on the bottom of the dish; then swim about for a short time but would soon settle to the bottom again. By the thirteenth day, all the larvæ had become loosely attached to the substratum and the tentacles had acquired their characteristic pinnate branches. Spicules had been developed, so that now for the first time a certain basis for differentiation was present. From the morula stage, some of the larvæ had shown a light pink color, known to be characteristic of the eggs and embryos of *Plexaura flexuosa*. Others were lead colored. These color differences had not, however, been thought dependable criteria for separating the larvæ from one another. With the development of the spicules, it becomes at once apparent that, as predicted, the pink embryos were those of *P. flexuosa*. The lead-colored larvæ showed spicules characteristic of the genus *Gorgonia*. The color of the spicules indicated *G.* (*Pterogorgia*) *acerosa* as the most probable species.

Ecological Changes on the Tortugas Reef since 1910

The writer first had an opportunity to study the Tortugas coral reefs in June 1910. During the five seasons following, the greater part of the time spent at the laboratory was devoted to studying the ecology, growth rate, recovery from destruction by storms, etc., of the Alcyonarian fauna. In the course of these studies the physical characteristics of the reefs, the identity and distribution of the characteristic fauna and flora, as well as ecological changes taking place, were observed and recorded. On visiting this region again during the past summer after the passage of thirteen years, many striking changes were recognizable. The most extensive change was physical in nature. North of Loggerhead Key there extends a reef, upon the surface of which both the stony corals (*Madreporaria*) and alcyonaria formerly grew luxuriantly. Now as the result of some changes in current action or as the result of severe storms, the east side of this reef area, for as much as a third of a mile in from the edge of the channel, is entirely covered by white coral sand with only here and there scattered alcyonarian colonies or an *Orbicella* head extending above the broad expanse of sand. This encroaching of the sand upon a formerly active reef area occurs from the end of Loggerhead Key to the north end of this reef, a distance of about two miles. The deposition of sand upon this reef took place sufficiently long ago to allow, within the interval since its occurrence and the present time, the establishment of a luxurious growth of turtle grass over a large portion of the sand-covered area farthest from the channel. Here apparently the sand is shallower and not so much subjected to movement due to currents, as is evidenced by the establishment of the turtle grass and by the presence of many alcyonarian colonies which extend for perhaps half their entire height above the surface of the sand.

A single observation is, of course, inadequate to form a certain basis for judging whether or not this covering of the active reef with sand is going on at the present time. The appearance of the whole area would, however, lead one to believe that the process is still in continuous operation.

The destruction of the alcyonarian fauna on White Shoal which was almost complete in October 1910 has, following its reestablishment in the following five years, taken place once more, so that today the fauna is normal only about the borders of this shoal in relatively deep water.

In contrast to the destruction of almost all visible organisms over an extensive area of reef, one species of madreporarian coral, *Acropora muricata,* has, within the time interval here considered, increased greatly in abundance and widely extended its distribution. Due to some disturbance in the environment, practically all representatives of this species were destroyed by the "black water" in 1873. In 1910 large areas on the reefs, both on the east and west sides of Loggerhead Key, were covered by *A. muricata* skeletons in various stages of disintegration. Living specimens were exceedingly rare. At only two places, one on each side of the Key, was there present any considerable growth of this species. Even here no extensive masses, so characteristic of this species when growing under favorable conditions, had been established.

In the period between 1910 and 1917 there was a very gradual spreading from these two chief centers of dispersal. In the earlier years dispersal took place very slowly; a few small specimens would be found each year at greater distances from the few colonies which had survived the almost total destruction in 1873. The dispersal was so gradual that careful observation and comparison with previous records were sometimes necessary to appreciate that the distribution was at all wider than during the immediately preceding season.

When these reefs were first visited in the past summer, even the most cursory observation was sufficient to show that the reestablishment of this species was going on at a greatly increased rate. However gradual the change might have appeared had the reefs been observed each year, the change in conditions after thirteen years was very impressive. Large, dense growths have been established at the original points of dispersal. About the peripheries of these masses the bottom was covered with a continuous carpet of broken branches, most of which were still alive. The central portion of the mass extended some 10 feet above the general reef surface, which was at a depth of approximately 4 fathoms. Several of these "scrubs" were at least 50 feet in diameter and had reached the stage in their development when the entire surface was a tangled mass. All interstices between the actively growing erect branches were filled with fragments broken from higher levels. Throughout its depth, the mass had become relatively dense in contrast to the open reticulate condition ordinarily found in younger growths.

From the two previously mentioned centers dispersal has taken place, until now numerous specimens occur on the east side of the Key over the entire length of the reef up to the region where the covering of this side by shifting sand has taken place. Some of these specimens are thus located more than a half mile from the original center of dispersal. On the reef west of Loggerhead Key the formation of large masses has been of more frequent occurrence. Dispersal has also taken place over wider areas, but on the other hand has not been so continuous. Consequently, extensive areas where no *Acropora* occur are frequently encountered. Young specimens were observed at least one mile from the location of the only colonies known to exist 20 years ago.

Conditions now found give very sharply the impression that the reestablishment of this species to its former place as the dominant madrepore on large portions of the Tortugas reefs is going on with increasing momentum from year to year. A reef characterized by the presence of *Acropora muricata* as the most abundant coral will within a relatively short time again be an outstanding characteristic of this region.

Changes in the alcyonarian fauna were in general much less striking than noted above for the madrepores. Many areas entirely denuded of gorgonians in the course of my earlier studies have now been covered by dense growths. Since the life span of the greater number of these forms is not more than 5 years, two or three generations may have come in since all specimens were removed from a number of the large *Orbicella* heads, but there was nothing in the appearance of the present fauna to indicate any unusual condition.

Twenty of the concrete disks upon which specimens of several species of *Alcyonaria* were cemented for growth records in my earlier studies were recovered.[4] In most instances the original specimens had disappeared. Some of the disks now bear specimens of coral of several species; most of them, however, were covered with algæ alone.

Upon one disk a colony of *Plexaura flexuosa,* for which the usual span of life is not more than 5 years, was flourishing and gave every indication of being the original specimen planted on the disk 17 years ago. While it has been known that *Gorgonia flabellum* and *G. acerosa* have an indefinite span of life, no specimen of the other common Tortugas species has previously been observed to persist for nearly this length of time.

Calcium Equilibrium in Sea-Water, by Haldane Gee

Previous investigators have discussed the bacteria as possible factors in the deposition of the calcareous muds of the Tortugas area. They consider primarily the production of ammonia by the physiological activity of bacteria and its effect on the equilibrium. Their conclusions differ as to the significance of the microorganisms in the process. A second factor, carbon dioxide, which is also a common bacterial product, has received little experimental treatment in these earlier publications.

During the current season, the writer obtained information on the problem from the physico-chemical standpoint which can be used in evaluating both the ammonifying and carbonating influences of the bacteria. These experiments consisted essentially of aerating sea-water in a specially designed apparatus which eliminated biological activity. It was found that calcium carbonate could be precipitated from the water at normal temperatures by reducing the total carbon dioxide content. The sea-water lost 5 per cent of its total calcium when agitated with CO_2-free air. A highly alkaline pH, such as may be caused by the introduction of ammonia, is not an essential factor for precipitation. Results indicate that production and utilization of carbon dioxide by organisms in the water exert more important influences on the equilibrium than does the production of ammonia.

The bacteria common to the area are capable of producing and withstanding high concentrations of ammonia, and are precipitating factors if this property only is taken into account. The amount actually produced in situ, however, can not be determined quantitatively with present methods. The foregoing experiments on carbon dioxide tension in the water show that if the organisms also produce carbon dioxide they may be regarded qualitatively as re-dissolving agents instead of as precipitating factors. A stock of cultures of typical organisms from the Tortugas is being more fully studied from the standpoint of carbohydrate metabolism. This further work indicates that the bacteria can not yet be regarded even qualitatively as accessory factors in the laying down of the muds.

Aerobic bacterial activity was not intense in fresh water and fresh mud samples from the region. Reducing conditions in the mud suggested that there may be a flourishing population of anerobes which may affect the equilibrium. Such anerobes, if present, have yet to be cultivated.

The investigation weakens the bacterial hypothesis of the origin of the calcareous deposits. Conversely, it indicates that carbon dioxide demands of calcareous algæ and other marine plants are important in inducing the precipitation of calcium carbonate and in rendering calcium available for animals. It is probable that plant activity assists the building of coral skeletons and the deposition of the Florida beach rock.

Ecology and Physiology of an Earthworm of the Intertidal Zone,
by James Nelson Gowanloch

Studies on the physiology of a remarkable marine earthworm were carried out at Tortugas. This form, tentatively identified as *Pontodrilus bermudensis* Beddard, is abundant on the Dry Tortugas, yet appears to have hitherto entirely escaped notice in that island group. The investigations included an analysis of the normal ecology of the species, its feeding reactions, the factors controlling its distribution and abundance, its tolerance of hypotonic and hypertonic media and of the unantagonized cations of sea-water, its migrations, dispersal, survival under lowered oxygen pressures and its oxygen consumption under a variety of physiological conditions. A series of tests was used to evaluate directly the rôles played by the sooty tern, *Sterna fulginosa* Gmelin, and the noddy tern, *Anous stolidus* (Linnæus), as possible vectors in the island-to-island transport of this oligochæte with quite positive results.

The experimental studies clearly established that this species of earthworm possesses remarkable physiological attributes involving a high degree of adaptation to sea-beach life. Its distribution in nature is directly controlled by the distribution of windrows of the sea-weed *Sargassum* of which alga seven species drift ashore on the Tortugas and constitute probably the entire food of this animal.

This earthworm was found to survive apparently unaffected temporary immersion in the sea to a depth of over 500 meters, exposure among the coral reefs for 22 days and submergence in shallow sea-water for the entire period of 74 days available for these experiments.

Its survival in conditions of lowered oxygen pressure induced by various methods demonstrated an astonishing resistance to a practically anaerobic environment.

The detailed results of the studies of this earthworm, which exhibits so remarkably an adjusted reversion to marine life, will be published at an early date.

Continuation of Studies of Metamorphosis of Larvæ of Ascidians,
by Caswell Grave

From June 25 to August 4, experimental studies of larvæ of an undescribed species of *Polyandrocarpa* and of *Phallusia nigra* were made in order to ascertain more specifically the conditions under which metamorphosis may be accelerated.

Polyandrocarpa n. s.

The results of these experiments with *Polyandrocarpa* and of studies made during two preceding summers with *P. tincta* and *Symplegma viride* show that the free-swimming period of larvæ of these species, and presumably of all species having the *Botryllus* type of larva, may be greatly shortened by subjecting larvæ either to a series of changes in intensity of light or to repeated intervals of mechanical stimulation.

The methods of experimentation found to be more or less effective in accelerating physiological processes that underly metamorphosis of these larvæ, enumerated in the order of their effectiveness, are as follows:

(1) One-minute intervals of darkness, alternating with one-minute intervals of light, repeated in series.
Very effective this summer in 28 of 29 trials.
(2) Five-minute intervals of darkness alternating with five-minute intervals of light, repeated in series.
Very effective this summer in 10 of 12 trials.
(3) One-minute intervals of mechanical impacts of the knocker of an electric bell, transmitted through a shelf of wood to a vial containing larvæ, alternating with one-minute intervals without mechanical stimulation, repeated in series.
Variously effective this summer in 5 of 9 trials.
(4) Mechanical agitations of water in a vial by slowly filling a pipette with the water and slowly expelling it at one-minute intervals with force just sufficient to set all larvæ in movement. Repeated in series.
Somewhat effective this summer in 1 of 2 trials.
(5) Mechanical agitations of water in a vial as in (4) but at five-minute intervals. Repeated in series.
Somewhat effective this summer in 1 of 2 trials.
(6) Differences in intensity of light in the lower and upper levels of a vial, produced by a band of black paper 2 cm. in width, wrapped about the lower end of the vial.
Somewhat effective this summer in 5 of 12 trials.

Thus, while changes in intensity of light, when repeated at intervals of one minute or five minutes have shown a more consistent and much greater effect in accelerating processes involved in the metamorphosis of the larva of *Polyandrocarpa* than any corresponding series of mechanical stimuli, yet some of the latter have been sufficiently effective to show that the mechanism involved in metamorphosis is probably not photochemical in nature, but is such that no specific stimulus is required for its activation.

Several attempts were made with specially designed apparatus to induce metamorphosis by stimulation of larvæ with an electric current, but, on account of the great conductivity of sea-water, they did not succeed. The relatively strong current that was repeatedly made to flow in the sea-water, filling the observation chamber, had not the slightest stimulating effect on the larvæ, hence it is not yet known whether metamorphosis can be accelerated by electrical stimuli.

The assumption has been entertained that the processes underlying metamorphosis are conditioned or activated by by-products of larval activity, *i.e.*, by substances formed during muscle contraction or nerve function, from which it follows that any stimulus that increases the activity of a larva will correspondingly shorten its free-swimming period.

But, unfortunately for so simple a solution of the problem, certain observations and results of experiment do not seem to support it. If metamorphosis occurs in a larva when substances resulting from activity reach a certain critical concentration, then all larvæ should undergo metamorphosis after an approximately equal amount of swimming, but that this is not true is conclusively shown by the following results of experiments with two broods of larvæ:

In a brood liberated July 30, an epidemic of metamorphosis was induced by 30 one-minute exposures to darkness, each followed by a one-minute exposure to light; whereas, in another brood, liberated July 29, not a single instance of metamorphosis had occurred five hours after liberation, during three of which the larvæ had received 90 one-minute exposures to darkness, each followed by a one-minute exposure to light. The effect of each change in light intensity thus brought about caused each larva to swim vigorously.

The time in the life of a larva when the disruptive process of metamorphosis occurs is therefore not primarily determined by factors due to activity, although they may play an equally important rôle.

In the cases of the two broods just cited, one at the time of its liberation was in a condition of "susceptibility" to the effect of changes in light intensity, whatever the nature of this may be; the other lacked this "susceptibility" and had not acquired it 5 hours after liberation—"susceptibility" being a name for a factor that varies greatly in the time of its appearance in different broods of larvæ. It is probably due or associated with the development or differentiation in the larva of some yet unknown structure or substance that in no observable way affects the form, structure or activities of the larva and does not seem to be closely correlated with age.

The existence of such a susceptibility factor was made evident by the results of the work of last summer and it was referred to and briefly discussed in the report for the 1929 Year Book (pages 284–286). At that time it was suspected to be more or less directly correlated with the age of the larva, but no satisfactory way to investigate the problem then presented itself, for the reason that in *Polyandrocarpa* the larvæ are brooded and hence not subject to observation until liberated.

Phallusia nigra

Unexpectedly this aspect of the problem found a favorable form for its further study this summer in *Phallusia nigra*, the larvæ of which are not brooded but can be reared in great numbers from artificially fertilized eggs. Larvæ known to be the same in age are thus available for observation and experiment. The susceptibility factor was here found not to be correlated with age but to show in the time of its appearance an even more extreme variability than in *Polyandrocarpa;* hence it is probable that in *Polyandrocarpa* also, variability in the time of development of the susceptibility factor is due primarily to differences in the mechanism of heredity of the larvæ.

In the life history of *Phallusia nigra,* a larva of the *Amaroucium*-type is found that differs fundamentally in structure from that of *Polyandrocarpa, Symplegma, Botryllus,* etc. It was used for experiment to ascertain whether the duration of its free-swimming period may, like that of the larva of *Polyandrocarpa,* be shortened by subjecting it to treatment with a series of changes in light intensity or to a corresponding series of mechanical stimulations. The results of work done with this species show that:

(1) Unlimited numbers of larvæ of the same age and parentage may be obtained at will throughout the summer by artificially fertilizing the eggs of an adult individual.

(2) The time interval from fertilization of eggs to the hatching of larvæ varies with temperature from about 7 hours 20 minutes to about 8 hours.

(3) Very great diversity is found in the duration of the free-swimming period of larvæ of the same parent. Under laboratory conditions, in which temperature and light remain relatively constant, the duration varied from 2 hours to 4 days.

(4) Great variation in the interval between hatching and the first occurrence of metamorphosis is found in broods of larvæ of different parents; *i.e.*, variation in the time of development of the "susceptibility factor." In some broods metamorphosis began to occur automatically about 2 hours after hatching; in others, under the same external conditions, it was many hours before the first larva metamorphosed.

(5) The duration of the free-swimming period is greatly affected by substances produced during the development of relatively large quantities of eggs and the same accelerating effect is produced by by-products of metabolism of relatively large numbers of larvæ; *i.e.*, metamorphosis is greatly accelerated in larvæ that are placed in water in which eggs have developed or when larvæ are crowded in a relatively small quantity of water.

(6) Experiments show that changes in the intensity of light are effective in shortening the duration of the free-swimming period of larvæ, provided the susceptibility factor has developed, and provided the larva is permitted to determine by its own activity the sequence with which the changes in intensity occur. The arbitrarily determined rates of intensity-change (one per minute or one at five-minute intervals) that are so effective in inducing metamorphosis in the larva of *Polyandrocarpa* were relatively ineffective with the larva of *Phallusia;* but if *Phallusia* larvæ are permitted to swim for periods of time varying with the appearance of the susceptibility factor (1 to 4 hours) in a slender shell vial (6 by 1.8 cm.), the lower end of which is jacketed with a band of black paper about 2 cm. in width, a significant acceleration in metamorphosis may be expected. Observations of larvæ under these conditions show that they are more or less constantly active—now swimming upward into the relatively lighter part of the vial, then swimming down and disappearing in the relatively dark chamber at the bottom, each larva swimming up and down with its own rhythm. The following record of an experiment of this kind is representative of the several that were made:

Eggs of an adult *Phallusia* fertilized at 5^h 50^m a.m., 7/12.
Larvæ hatching at about 1^h 30^m p.m.
Larvæ transferred at 1^h 35^m p.m. to 3 shell vials (6 by 1.8 cm.) each containing fresh sea-water.
Formalin added to each vial at 3^h 45^m p.m.
Control Vial: 104 larvæ in vial without black paper jacket, exposed to light of uniform intensity for 2 hrs. At 3^h 45^m p.m. two larvæ had metamorphosed. 1.9 per cent.

Experimental Vial: 113 larvæ in vial with a jacket of black paper, 1.5 cm. in width, milling up and down for 2 hours. At $3^h\ 45^m$ p.m. 49 larvæ had metamorphosed. 43.3 per cent.

Experimental Vial: 62 larvæ in a vial without black paper jacket. Exposed to light of uniform intensity from $1^h\ 35^m$ to $2^h\ 35^m$ p.m. Given 30 one-minute exposures to darkness, each followed by a one-minute exposure to diffuse light, from $2^h\ 45^m$ to $3^h\ 45^m$. At $3^h\ 45^m$ p.m. 8 larvæ had metamorphosed. 12.9 per cent.

(7) Mechanical stimuli produced in series by slowly filling a pipette with water from the vial containing larvæ and slowly expelling it, once per minute, were less effective than corresponding series of light intensity changes. In five experiments made on larvæ immediately after hatching the following percentages of metamorphosis occurred:

1. After 60 agitations, $4^h\ 00^m$ to $5^h\ 00^m$ p.m., 0 p. ct.: Control 0 p. ct.
2. After 60 agitations, $2^h\ 52^m$ to $3^h\ 52^m$ p.m., 1.3 p. ct.: Control 0 p. ct.
3. After 120 agitations, $2^h\ 52^m$ to $4^h\ 52^m$ p.m., 6.7 p. ct.: Control 0 p. ct.
4. After 90 agitations, $3^h\ 05^m$ to $4^h\ 35^m$ p.m., 0 p. ct.: Control 0 p. ct.
5. After 180 agitations, $2^h\ 20^m$ to $6^h\ 10^m$ p.m., 6 p. ct.: Control 3 p. ct.

In three experiments made on larvæ the day following hatching, the following percentages of metamorphosis occurred:

1. After 60 agitations, $9^h\ 35^m$ to $10^h\ 35^m$ a.m., 0 p. ct.: Control 0 p. ct.
2. After 60 agitations, $12^h\ 40^m$ to $1^h\ 40^m$ p.m., 11.6 p. ct.: Control 0 p. ct.
3. After 60 agitations, $9^h\ 20^m$ to $10^h\ 20^m$ a.m., 0 p. ct.: Control 1 p. ct.

Tests for Mitogenic-rays, by Caswell Grove

Eight tests with two pure strains of yeast and developing eggs and larvæ of *Phallusia nigra* were made for the purpose of demonstrating the mitogenic-rays that are said, by A. Gurwitsch, to emanate from rapidly growing yeast (and other cells) and to be revealed by their effect in accelerating developmental and growth processes in closely adjacent organisms.

The eggs and larvæ of *Phallusia nigra* seemed unusually well suited to register effects of an agency of this kind because of the rapidity with which the larva develops from the egg and because its metamorphosis may be greatly accelerated by light intensity changes and mechanical stimulation.

Strain V of *Saccharomyces elipsoid,* supplied by Dr. Roland LaGarde from the Shaw School of Botany, was used in the first two tests, and cultures from Strain No. 2335 of *S. cerevsiæ* (Hansen), supplied by Dr. O. W. Richards, in tests 3 to 8, inclusive.

The yeast cultures were grown in the Williams culture medium.

The container for developing eggs and larvæ, permeable to mitogenic-rays (ultra violet), was a test-tube of fused quartz (150 by 20 mm.). A glass test-tube of the same dimensions served as the non-permeable container for the control lots of eggs and larvæ.

For each test, 250 c.c. of culture medium in each of two Erlenmeyer flasks of 300 c.c. capacity was inoculated with yeast. Twenty-four hours later *Phallusia* eggs were fertilized in a 50 c.c. beaker and from this stock equal quantities of eggs were transferred to the test-tubes, each containing 30 c.c. of water. The test-tubes were then so placed in the Erlenmeyer flasks that the yeast culture surrounded the parts containing developing eggs. During the entire period of each test, the flasks stood in sea-water to a depth of 5 cms. and by this means the temperature was maintained at 28° to 30° C.

Examinations of the eggs in beaker and test-tubes were made from time to time and note taken of the rates of development, and especially the time at which hatching of larvæ occurred in each. From 3 to 4 hours after larvæ had hatched, formalin was added to both tubes, and counts were then made of the number of metamorphosed and unmetamorphosed larvæ present.

Six of the eight tests were carried out under satisfactory conditions. Growth of the yeast in these was good and a dense cloud of yeast cells obscured the immersed parts of the test-tubes throughout the entire period of development and more than 99 per cent of the *Phallusia* eggs developed. Two tests were discarded for the reason that the *Phallusia* eggs in these showed a low percentage of development.

It is difficult to decide whether or not the results obtained can be interpreted as showing effects due to mitogenic rays. Certainly no acceleration in development occurred, for hatching of larvæ took place in each test practically simultaneously and to the same extent in both test-tubes. Differences in percentages of metamorphosis that occurred in the test-tubes, shown in the table, may be interpreted as evidence of an effect of mitogenic-rays, since in three of the experiments (1, 4 and 7) the percentages of metamorphosis of larvæ in the quartz tube exceeded those in the glass to a much greater extent than in the two (3 and 5) in which metamorphosis in the glass tube exceeded that in the quartz. When, however, account is taken of the great variability in the duration of the free-swimming period shown by larvæ of *Phallusia*, all differences in the results of these tests and even greater might well be due to this factor.

Number of tests	Date	Duration of test	Number of larvæ hatched in—		Number of larvæ metamorphosed in—		Per cent of metamorphosis in—	
			Quartz	Glass	Quartz	Glass	Quartz	Glass
		hrs. min.						
1	July 12	10 17	351	335	205	155	58	46
3	July 14	11 20	229	254	9	14	3.9	5.5
4	July 25	11 45	1329	1233	39	8	2 9	.6
5	July 26	12 20	434	453	86	101	20	22
7	July 31	12 40	1005	888	40	8	3 9	.9
8	Aug. 1	11 30	1060	996	56	52	5.28	5.2

A Study of the Physiology and Classification of Marine Amœbæ,
by D. L. Hopkins

The object of this study was to ascertain (1) the effect of past cultural conditions on the rate of locomotion of amœbæ, and (2) whether the rate of locomotion under constant and well-defined conditions was sufficiently constant to justify its use as one of the criteria for the classification and as an index of the physiological condition of the amœbæ.

The amœbæ used for this investigation were fan-shaped, broader than long, and usually had a hyaline anterior edge comprising a considerable portion of the length. While in many respects they fit the description of *Flabellula mira* Schaeffer, in others they correspond more closely to *Flabellula citata* Schaeffer. Therefore it would perhaps be best to leave them unnamed, for the present.

Several of these amœbæ were isolated individually and from each a clone was grown. Clone No. 1 was studied extensively, while the other clones were kept going and thus preserved for study. When No. 1 has been studied sufficiently it will serve as a known *type clone* to which other clones may be compared.

The following facts concerning clone No. 1 were established:

(1) The average rate of locomotion in artificial sea-water of several hundred amœbæ, which were taken from 50 or more one-week-old normal sea-water cultures made up by adding 6 grains of wheat to a petri dish of sea-water, was 43μ per min. (temperature 29° to 34° C.). The average rate of amœbæ from individual cultures varied from 30μ to 50μ per min., 64 per cent of the cultures giving average rates between 39μ and 46μ per min. The rates of individual amœbæ varied between 20μ and 60μ per min.

(2) These amœbæ can be cultured with equal facility in normal sea-water having a hydrion concentration anywhere from pH 4.0 to pH 9.0; neither does culture at these varying hydrion concentrations affect the rate of the amœbæ in artificial sea-water.

(3) They can be cultured in McClendon's Artificial Sea-water; isotonic mixtures of NaCl, KCl and $CaCl_2$; of NaCl and $CaCl_2$; of $MgCl_2$, $CaCl_2$, NaCl and KCl. The rates in artificial sea-water of amœbæ cultured one week in these mixtures were normal.

(4) They can not be cultured in isotonic solutions of the single salts; NaCl, $CaCl_2$, NaBr, $MgCl_2$, $MgSO_4$, KCl or in 0.5 M.$NaHCO_3$ plus NaCl until isotonic. However, after remaining one week in isotonic solutions of NaCl, of $CaCl_2$, of NaBr, or of $MgCl_2$ they encysted and then on being returned to normal sea-water culture medium excysted, grew, multiplied and at the end of a week in normal sea-water culture their rates in artificial sea-water were again normal. On the other hand, amœbæ remaining for a week in isotonic solutions of $MgSO_4$, of KCl and of $NaHCO_3$ plus NaCl did not survive.

(5) They can be cultured in distilled water to which has been added wheat, and in any concentration of sea-water—from sea-water diluted many times to sea-water concentrated six or eight times. When a culture dries up they encyst, and readily excyst when distilled water is added. They can be dried in a $CaCl_2$ desiccator for two days and still excyst on the addition of distilled water. They have vacuoles resembling contractile vacuoles in high concentrations of sea-water, but these are actively contractile only in dilutions below one-half sea-water. The vacuoles contract very actively in distilled water cultures. Amœbæ from one-half sea-water cultures up to three times normal give normal rates in artificial sea-water, those from cultures above three times sea-water give low rates, and those from cultures below one-half sea-water require some time for adjustment before they will move at all.

(6) The rate shortly after excystment in normal sea-water is low, then becomes high, by the end of a week becomes normal, and again becomes low just before encystment.

(7) Various types of unfavorable conditions will cause encystment aside from the instances mentioned above.

In conclusion it would appear that the rate of locomotion under well-defined conditions would be a useful criterion for use in the classification of this group of amœbæ, and also a good index of the physiological condition of the amœbæ.

Observations upon Distribution and Behavior of Tortugas Fishes,
by W. H. Longley

By use of a 30-foot otter-trawl it has been possible this year to add many species to the local fish fauna. Some were obtained in the 10-fathom channels between Loggerhead Key and Garden and Bird Keys, others in six rich hauls at depths between 70 and 235 fathoms south of the Tortugas group, at and below the brow of the slope which dips sharply into the trough of the Florida Strait.

The deep-water species, about 50 in number, include several which are little known and some known heretofore only from considerably greater depths. The fauna to which they belong is rich and the bathymetric distribution of its members so orderly that it invites investigation.

In my previous reports, an attempt to learn something regarding the power of the gray snapper to distinguish between two simple patterns has been reported. The earlier experiments were made with colonies living under one or another of the wharves of Loggerhead or Garden Keys. The membership of these groups certainly varied from day to day, for which reason among others it seemed desirable to undertake the inquiry anew.

Twenty-five gray snappers (*Lutianus griseus*), of an average length of about 10 inches, were introduced into and confined alone within a landlocked portion of the moat about Fort Jefferson. Since these fishes soon learn to distinguish formalin-preserved from fresh minnows fed to them, the use of *Cassiopea* tentacles sewn in the mouths of some to make them distasteful was abandoned.

Formalin-preserved minnows (*Hepsetia stipes*) were marked with silver nitrate with a single longitudinal black stripe on either side. Fresh fishes of the same sort were marked by the same means with two black bands encircling the body. The two were then fed alternately until the snappers discriminated rather definitely between them, taking the one sort readily and regularly and rejecting most of the others without seizing and holding them even for an instant.

The conditions were then altered, and striped fresh fishes and banded preserved ones were fed along with the two sorts earlier used.

The snappers' power of readjustment is great, and fresh fishes, even when they bear the mark which has long distinguished the unpalatable ones, are usually eaten. But the effect of experience appears in the fact that striped fresh fishes in my tests were rejected with twice the frequency of banded fresh ones. Striped fresh fishes, when taken, were taken too with greater hesitation than banded ones, and preserved striped fishes were rejected to the end very much more commonly than banded preserved ones. As a matter of fact, the latter are almost always seized before being rejected, whereas a large part of the former are allowed to sink to the bottom untouched. There seems, therefore, no reason to doubt that the gray snapper can discriminate between such simple patterns as those mentioned, and is able to form associations between either and the palatability or unpalatability of the food-fish displaying it.

Studies on the Trematodes of Tortugas Fishes, by H. W. Manter

During the summer of 1930, a taxonomic study of the trematodes of Tortugas fishes was undertaken. Very early in the collection of these parasites it became evident, as has already been suggested by the work of Linton, Pratt, Miller and McCoy, that the trematode fauna of Tortugas is one of the most varied in the world. Relatively shallow warm waters with abundant fish and molluscan fauna seem to offer ideal conditions for these parasites. The author was especially fortunate in the effective facilities of the laboratory in obtaining fish hosts. Approximately 675 hosts were examined, and these included 130 different species of fishes. Approximately 78 per cent of these species contained trematodes, and since only one specimen of a number of species was examined, it is safe to estimate that over 80 per cent of the different kinds of fishes at Tortugas are hosts to trematodes. Selachians were, of course, not favorable hosts for trematodes and very few trematodes were found in parrot fishes, blennies and Syngnathids. The following fifteen species of fishes were hosts to four or more species of trematodes: *Acanthurus cœruleus, Anisotremus virginicus, Calamus bajonado, Calamus calamus, Coryphæna hippurus, Eques acuminatus, Hæmulon flavolineatum, Hæmulon plumieri, Hæmulon sciurus, Kyphosus sectatrix, Lutianus griseus, Ocyurus chrysurus, Pomacanthus arcuatus, Sardinella humeralis, Selar crumenopthalmus.* The largest number of different kinds of trematodes from one host was collected from the white grunt (*Hæmulon plumieri*) which is a host to at least ten species of trematodes. The most remarkable individual infection occurred in a yellow grunt (*Hæmulon sciurus*), which contained eight different species of trematodes simultaneously, as well as acanthocephala and nematodes.

A preliminary survey of the trematodes collected indicates that approximately 103 different species were found from fishes. These include practically all the species collected by Linton and Pratt at Tortugas, most of those reported from Bermuda by Linton, and over 40 additional forms. Most of these latter will doubtless be new species, and some of them seem to fit into very interesting niches in the systematics of the group.

A very interesting aspect of the summer's work developed from the opportunity to collect parasites from a number of deep-sea fishes. Of twenty species of fishes trawled from a depth of 100 to 200 fathoms, all but two species contained trematodes. This finding indicates that trematodes are as common in the deep as in the shallow waters. Eleven species of trematodes were represented, only one or two of which were found in any of the shallow-water fishes examined. The trematodes of deep-water fishes, therefore, tend to be distinct from those of near-by shallow-water fishes. Most surprising was the discovery of several species of trematodes characteristic of the cold waters of the Maine and North Europe coast. These include *Derogenes varicus, Lepidapedon elongatum* and *Lepidapedon* *rachion*. All three of these species are well known in northern waters and have been studied by the author from a collection from the Maine coast. They are not known from collections at Beaufort, North Carolina, nor have they appeared at all in the examination of hundreds of shallow-water fishes at Tortugas. This discovery leads to the conclusion that the trematode fauna of deep-sea fishes of the tropics is more similar to that of arctic waters than to the near-by shore fauna, and that temperature is an important factor in the distribution of trematodes of marine fishes. A fourth species collected from a fish from a depth of 200 fathoms is very closely related to *Gonocerca phycidis*, a very distinct genus hitherto known only from the icy waters of the Maine coast. None of the 90 or more species of trematodes collected from the shallow-water fishes are represented in northern waters. Further work on deep-sea forms will probably emphasize this relation to cold-water forms and contrast to the adjacent but warm-water fauna.

In the course of the summer's work several points of interest and which may suggest further work were encountered. A mutilated and regenerated specimen of *Helicometra torta* was collected from the Nassau grouper (*Epinephelus striatus*). The body had been cut or torn on the right side not far from the posterior end in such a way that a triangular or wedge-shaped portion was entirely missing on that side. The gash was deep enough to extend nearly to mid-body. Edges of the wound had completely healed. The right cecum of the digestive system had been severed, but both ends had closed, thus leaving a short section of the digestive system completely cut off. This isolated portion of the intestine showed no signs of degeneration. The right vitelline field was interrupted by the cut and those follicles posterior to the mutilation showed signs of disorganization, a number having broken up into yolk granules. Perhaps the most striking effect of the lesion was the disappearance of the posterior testis. The wound must have reached this organ, with the result that the testis completely disappeared, except for a small cluster of black granules (resembling a fine precipitate). The worm had become partially castrated. This species normally always possesses two testes, although a related species, *Helicometra execta,* may have but one or even none. No other abnormality was evident in the specimen. The effects observed show that the vitellaria and the testes are the most sensitive organs, *i.e.*, those most easily upset, and this same observation has been suggested by certain other conditions in various trematodes. *Helicometra torta* possesses a very thin, delicate body and must be subjected to considerable abrasive dangers from the coarse calcareous food of the groupers. The same species occurs in the red grouper. The trematode is fairly hardy and regeneration experiments seem easily possible.

A peculiar case of hyper-parasitism was noted in specimens of *Lepocradium trulla* from the yellow tail (*Ocyurus chrysurus*). Within the ceca of several of these trematodes, occurred small protozoa about the size and shape of *Chilomastix*. They swam about very actively and seemed to be flagellates, although the flagella could not be discerned. They did not occur in all trematodes even in the same fish, but their presence was noted a number of times on different dates so that the condition is more or less general. Several smears of the intestinal content of the fish did not reveal any protozoa.

"Distomum fenestrum" Linton is a trematode collected by Linton from the intestine of various fishes at Tortugas and Beaufort, but always in an immature state. The absence of a pharynx is strong indication that this trematode is normally a blood parasite, although reported only from the intestine. During the summer this species was collected several times from the intestine of different fishes. In scrapings of the gills of a very small nurse shark (*Ginglymostoma cirratum*) (about one foot in length) numbers of this trematode were found. Since blood trematodes are often found in the vessels of the gills, a further search was made of the circulatory system of this host. Specimens of *Distomum fenestrum* were found in the heart, liver, spleen, kidney and stomach. Unfortunately all these specimens were still immature, so that the adult form of this trematode is still unknown. The heavy infection of the circulatory system of the young nurse shark indicates that the adult blood fluke will be found in this host. Side-tracked in a wrong fish host, this parasite seems to be able to maintain itself as a juvenile intestinal form. It is improbable that these fishes can act as intermediate hosts, since the large size of the worm would prevent its entrance into the circulatory system of a shark.

In addition to trematodes from fish hosts, material was collected from a loggerhead turtle, several green turtles and a frigate bird. A single loggerhead turtle (*Caretta caretta*) yielded six different kinds of trematodes, most of them in large numbers. Linton and Pratt each collected trematodes of different kinds from this host and it is interesting that three of the six in the present collection were not recorded by either. Three species of trematodes were collected from the green turtle (*Chelone midas*). The frigate bird (*Fregata aquila*) contained large numbers of *Galactosomum cochleariforme* and also numerous hemistomes.

Bioelectric Potentials in Valonia, by Gordon Marsh

The existence of differences of potential in living cells gives rise to, as one of its primary problems, the question as to the nature of the physicochemical mechanism involved. The work of Lund and some of his students has furnished unequivocal evidence that the mechanism in *Obelia,* frog's skin, onion root tip, Douglas fir, is that of an oxidation-reduction potential intimately linked with the respiratory processes of the cell. It is important that these studies be extended to differences of potential across a single cell or across a single layer of protoplasm, such as is afforded by the cells of *Valonia.*

The material was collected from the moat at Fort Jefferson and, from superficial morphology as well as from the magnitude of the potentials found, apparently consisted of both *V. macrophysa* and *V. ventricosa.* As the results obtained were fundamentally the same with both species no separation is attempted.

Potentials were measured with a Compton quadrant electrometer with lamp and scale; as used the instrument had a sensitivity slightly greater than 0.5 millivolts per millimeter. Current was measured with a Leeds and Northrup type R galvanometer of 2361 megohms sensitivity. Both instruments were calibrated with a 4-volt lead accumulator (half-discharged), a Weston voltmeter and two Leeds and Northrup 10,000 ohm dial boxes, using a divided circuit. No error was introduced by this method of calibration, as was shown by the agreement between calculated deflections of both instruments and the deflection observed. Shielding was found to be unnecessary.

Experiments were performed upon both intact cells and cells impaled on capillaries by the method of Jacques and Damon. Artificial sap was made up according to the formula of Osterhout for the natural sap of *V. macrophysa.* Lead-lead chloride electrodes were employed save when low resistance was required, zinc-zinc sulfate (saturated) electrodes serving in this capacity. The latter were non-polarizable by currents of the intensity used.

M/2000 KCN in sea-water produced a reversible depression of the potential. Half-saturated solutions of ether in sea-water likewise produced a reversible effect, but, as is frequently the case with ether, the behavior of the potential was more variable than with KCN. Saturated ether solutions speedily produced injury and death. Both ether and cyanide in low concentrations are known to reversibly reduce the oxidation rate in living protoplasm.

It was found by Blinks (Year Book No. 28, p. 277) that a large counter-E.M.F. could be produced in *Valonia* by the action of an applied electric current. A few experiments were performed by the writer wherein the decay of the counter-E.M.F. with time was recorded after the passage of current. The shape of these "recovery curves" agreed with that found by the writer in similar experiments on the onion root tip (paper in press). The analysis is too involved for this report; suffice it to say that the equation expressing the change of E.M.F. with time demonstrates that the process of polarization can not be the piling up of inorganic ions at an interphase, but must rather be an oxidation-reduction phenomenon at intracellular "electrode" surfaces.

In addition to the above a number of exploratory experiments were performed, the results of which, due to the meager number of experiments in any one case, can not profitably be set forth.

The conclusion seems inescapable that the difference of potential across the protoplasmic layer of *Valonia* arises from an oxidation-reduction system of the type formulated by Lund.

On the Mechanics of Spiral Movement in Trichamœba sphærarum,
by A. A. Schaeffer

Practically all my time at the Laboratory this season was taken up in testing the effect of light on the mechanism of spiral movement in the marine ameba, *Trichamœba sphærarum.* This ameba was investigated for the special purpose of comparing the results with the striking reactions to light of another ameba, *Mayorella conipes.*

The reactions of *T. sphærarum* are found to agree almost perfectly with those of *M. conipes,* which indicates that the reactions are general for the amebas, since these two amebas belong to different families. The results show that the molecules are activated (through some of their atoms) by light of certain intensities so that they arrange themselves in different molecular patterns than when not activated. This difference is clearly shown in the amount of path which turns to the left as compared with the amount to the right, while the ameba moves around a thin glass rod.

This ameba becomes predominantly right-turning in a hypertrophied condition, which is the result apparently of somewhat unfavorable cultural conditions. In this respect this ameba agrees with three other species which have been investigated while in this condition. Some of these amebas were obtained from wild cultures, some from Doctor Hopkins' cultures and some from my own laboratory cultures.

Another result of great interest from this work on *sphærarum* is the way in which the various lengths of right and left sections of path may be arranged in a frequency series. That is, if one counts all sections of path in which the amebas moved halfway around the glass rod; next all sections where they moved once around the rod, and so on, the series of numbers so obtained corresponds very closely, in the higher categories, to the exponential series represented by the formula $4^{-(y-\frac{1}{2})}$ where y equals the length of the section. Three other species have been investigated in this respect and the formulas for these three species are, respectively. $2^{-(y-\frac{1}{2})}$, $2^{-(\frac{y-1}{2})}$, $3^{-(y-\frac{1}{2})}$.

These observations on *sphærarum,* therefore, furnish an important link in the chain of evidence pointing to a molecular organization in the protoplasm of amebas and to a conception of the organism as a *field,* probably chiefly electrical in character, which arises out of the properties of the molecules, more particularly as a result of their organization.

Still another line of evidence pointing to a molecular pattern in ameban protoplasm was obtained from *sphærarum* when comparing the path before and after eating a large particle of food. If the predominance of turns is to the left, before eating, then after about 30 minutes there sets in a strong predominance of right turns which lasts for several hours. In this case as in the case of the light experiments, it is presumed that the molecules become changed in the amount of and possibly in the direction of spiral twist.

These observations on *sphærarum* together with observations on other species of amebas made during the past several years, all of which are concerned more or less directly with the molecular organization of protoplasm, will be published soon in one of the biological journals.

I wish also to add an observation on spiraling on two frigate (Man o' War) birds made on July 1. These birds were captured by Dr. Gowanlock and with his assistance were blindfolded and released from the top of Loggerhead Key Light, about 50 meters high.

The first bird did not make any attempt to open its wings and fell to the ground like a plummet and was killed. The second bird was made to spread its wings only with great difficulty, and even then when released fell about 20 meters before it started to fly. It oriented to fly with the breeze, and after flying about 200 meters in a straight path it began to go in right-hand circles of from 50 to 100 meters in diameter. While the first 7 or 8 circles were made, the bird gained in altitude to about 100 meters, then it gradually lost altitude until with the fifteenth circle it was only a few meters from the water. It was then lost from view. The bird steadily receded from the Lighthouse and the fifteenth circle was about 1000 meters away, the path as a whole thus being a loose spiral. There was no soaring at any time.

These results conform to those of other birds and afford one more example of the universality of the spiraling mechanism in organisms. Incidentally it also shows the fundamental importance of sight in flying long distances.

Some Observations on the Crustacea of Tortugas, Florida,

by Waldo L. Schmitt

Some years ago Professor Henri Coutière monographed the American representatives of the tiny shrimps belonging to the genus *Synalpheus* (*The American Species of Snapping Shrimps of the Genus Synalpheus,* Proc. U. S. Nat. Mus., vol. 36, pp. 1–93, figs. 1–54). Such fine distinctions seemed to have been drawn between the species he described that the well-known carcinologist, the late Rev. T. R. R. Stebbing, was moved to remark that "in the discrimination of these species minute measurement plays an almost alarming part, because as the eyes are completely covered by the carapace, the vision of these creatures must be dim, and without compasses the members of the different species will never know one another apart. Perhaps, indeed, the numerous varieties may be the result of inconsiderate intermarriages."

I have long wanted to examine Coutière's species in the light of Stebbing's comment, and so welcomed the opportunity this past season of securing a number of living Synalpheids and noting their color in life. A preliminary review of this material seems to indicate that at least a number of the species and perhaps also their variations are linked with very striking and characteristic color differences. These affect the large chela, the small chela which is color-patterned after the larger one, the body, and often the appendages.

SPECIES AND COLORS OF THE SYNALPHEIDS EXAMINED

Neomeris Group

Synalpheus hemphilli Coutière—Ambulatory legs, maxillipeds, and chelipeds azure blue; chela likewise blue toward base of fingers, becoming indigo blue; fingers myrtle green, shading over into the bright orange ochraceous margins of the fingers; body quite colorless.

Synalpheus fritzmülleri Coutière—Chela more or less transparent apple green, darker toward extremities of fingers; fingers in some specimens perhaps as dark as bottle or French green; body more or less colorless, specked with quite numerous tiny red chromatophores.

Synalpheus fritzmülleri elongatus Coutière—Similar to preceding; chelipeds and second legs china blue, except anterior part of chela; fixed and movable fingers light parrot green.

Paulsoni Group

Synalpheus townsendi Coutière—Body and appendages colorless but finely and plentifully spotted with tiny red chromatophores; fingers of chelæ with noticeable greenish cast.

Synalpheus townsendi scaphoceris Coutière—Similar to preceding body and appendages, with slight bluish cast finely red speckled; fingers and anterior border of palm of large chela deep Paris blue.

Brevicarpus Group

Synalpheus brevicarpus (Herrick)—Distal half of large chela including fingers a bright light purplish rose red ("cerise"); body colorless or with very slight bluish tinge.

Synalpheus brevicarpus guerini (Coutière)—Hand of large chela gamboge yellow; anteriorly palmar border and fingers blue; body bright gamboge yellow.

Synalpheus brevicarpus subspecies indet.—Hand of large chela citron yellow; anteriorly palmar border and fingers pink; body citron yellow.

Lævimanus Group

Synalpheus mcclendoni Coutière—Quite colorless all over; fingers and anterior part of large chela pale ocher yellow overlaid and darkened with liver brown to hazel chromatophores.

Dr. J. F. McClendon, for whom one of the preceding species of *Synalpheus* was named, in his observations *On Adaptations in Structure and Habits of some Marine Animals of Tortugas, Florida* (Pub. No. 132, Carnegie Inst. Wash., 1910, pp. 55–62, pl. 1, fig. 2), mentions a species of Pontonid shrimp, *Typton tortugæ,* which seems never to have been described or recorded in systematic carcinological literature. It differs from the other two species belonging to this genus so that the figure given of it does not serve to place the species generically. I take this opportunity to supply some drawings of certain appendages, together with a few diagnostic remarks.

Typton tortugæ (new species)

Carapace but slightly inflated, smooth; a short, simple spine-like rostrum reaching about half the length of the eye-stalks; eye-stalks large, thick, swollen, cylindrical, nearly as long as the basal article of the antennular peduncle. On the anterior margin of the carapace above the base of the antennæ at the lower, posterior angle of the eye-stalk is a small laterally flattened, acutely ending spine-like projection corresponding to the supraorbital spines of *T. spongicola* Costa, though much smaller, less prominent, lower and more laterally placed. In *T. spongicola* the rostrum slightly exceeds the eyes, while the orbital spines reach about to the middle of the cornea; the eyes attain about a third of the length of the basal article of the antennular peduncle. The antennal scale is most rudimentary.

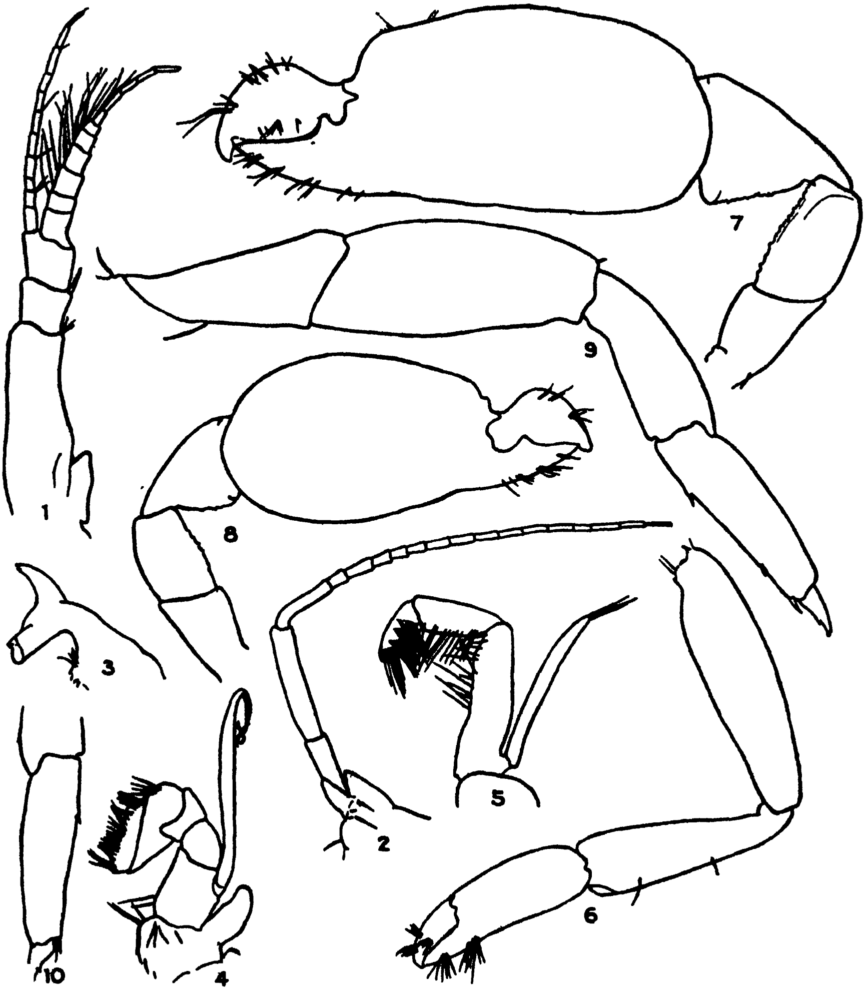
The orbital spine is indicated in McClendon's figure, but it is acute and not bluntly rounded as he has it, and is moreover about half the length of the rostrum.

The chelæ vary in shape and size between those figured by McClendon and here profiled. He has the fingers of the larger chela too slender and the gape between them too large.

The telson is distally armed with six spines as in *T. bouvieri* Nobili, but the median pair of spines is a little shorter than the intermediate pair.

Holotype—An ovigerous female 15 mm. long from extremity of rostrum to hinder margin of telson; taken by Dr. J. F. McClendon from a loggerhead sponge at Tortugas, Florida, July 1908.

At present this species is known only from the type and 12 other specimens collected by McClendon from the type locality. Though I examined two sponges rather completely and considerable portions of three others, of which one was nearly 3 feet in diameter, this year I did not find any specimens of *Typton* among hundreds of *Synalpheus brooksi* Coutière, with which McClendon found it associated.



Figs. 1-10. *Typton tortugæ*. All x 53, except chelæ, which are x 29; appendages from left side, chelæ as indicated. 1, antennule from below; 2, antenna from below; 3, mandible; 4, second maxilliped; 5, third maxilliped; 6, first leg; 7, right cheliped; 8, left cheliped; 9, third leg; 10, fourth leg, dactyl and propodus.

In a further investigation of the carcinological fauna of the Tortugas region a number of hauls were made with a thirty-foot otter trawl. Two successful hauls with this piece of apparatus between 180 and 237 fathoms brought to light a number of "deep sea" crustacea. More noteworthy among the sixteen odd species taken were eight specimens of that giant among isopods, *Bathynomus giganteus* A. Milne Edwards, and a new species of Portunid crab belonging to a genus, *Benthochascon*, heretofore known only from two specimens taken from 185 and 440 fathoms in the Andaman Sea.

Three specimens of *Bathynomus* were obtained from the first haul in 180 to 220 fathoms, and five specimens in the second haul in 220 to 237 fathoms. The largest specimen measures 10.5 inches long by 4.5 inches broad. In length it is scarcely more than an eighth of an inch shorter than the record specimen taken at a depth between 225 and 594 fathoms off the northeast coast of Ceylon. The species is comparatively rare in collections. Between 1890 and 1906 nine specimens were taken by the Royal Indian Marine Survey Ship *Investigator* in Indian Seas in the course of six hauls in from 195 to 740 fathoms, while seventeen specimens have been secured by various American vessels. The first specimen known to science was taken by the *Blake* in 1878 from 955 fathoms in the Caribbean Sea; two specimens were secured by the *Albatross* in 1885 and 1886 in the Gulf of Mexico and the Bahamas in 730 and 1186 fathoms respectively; six specimens were taken by the Bingham Oceanographic Expedition of 1925 off the coast of British Honduras north of Glover Reef in 366 fathoms; and, finally, the eight specimens recorded above were taken by the Yacht *Anton Dohrn* of the Carnegie Institution of Washington on July 31, 1930.

Distribution of Barnacles with Special Reference to Behavior of Larvæ, by J. Paul Visscher

A study of the barnacles of the region was made, more than 20 species being found of which several appear to be new to science. The behavior of the larvæ was of especial interest, not only with reference to their reactions to light and to gravity but especially their relations to the particular habitats in which the adult forms are found. Thus certain barnacles were found only on corals, others only on crabs, still others only in the gill chambers of crustacea, and yet others above tide line on piling. The most abundant form was *Lepas anatifera*, found on the buoys as well as on floating objects, while perhaps the most interesting was a new form found exclusively on the expods of the maxillipeds of the Florida crayfish, *Panularus argus*, while another form inhabits the gill chambers of this decapod.

Physiological Life-histories of Algæ, by Shigeo Yamanouchi

During six weeks at Tortugas, Dr. Yamanouchi studied particularly the local Phæophyceæ and Chlorophyceæ. Especial attention was paid some of the more difficult genera, such as *Caulerpa*. The attempt was made to secure reproductive phases of as many different types as possible, by recourse in many instances to modification of the usual environmental factors. Large collections were made for later morphological and cytological study.

BIOLOGY

Castle, W. E., Harvard University, Cambridge, Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3–28.)

In the past year the study of some problems in rabbit genetics has been brought to a conclusion and that of others has been begun or continued. Among projects completed, or rather laid aside for the present, may be mentioned the study of rabbit embryology in relation to racial size. In cooperation with Dr. P. W. Gregory the conclusion had been reached, as stated in last year's report, that the gametes (eggs and sperm) of rabbits of large racial size have a more energetic and rapid growth rate than is possessed by the gametes of small race rabbits. This conclusion is confirmed by additional studies made in the summer of 1929. As early as 40 hours after mating we find that the eggs of large race rabbits contain more numerous blastomeres than those of small race rabbits, and subsequently the large race egg or embryo continues to grow more rapidly, so that it attains a larger size at birth and later stages.

But at 30 hours after mating, eggs of large and small races seem not to differ in number of blastomeres. This we can account for only by assuming that the small race egg starts developing more promptly, even though its rate is less rapid. Perhaps the small race rabbit responds more promptly to the stimulus of mating and so discharges its eggs earlier from the ovary, or else the sperm reach and fertilize the eggs earlier because of the shorter distance they have to travel through the length of the uterus and oviduct, which are shorter in the small race. Although the small race egg possibly gets an earlier start, its less rapid developmental rate causes it to fall behind the large race egg at some point between the 30-hour and 40-hour periods. We hope to get more precise information about this difference and its causes when additional material is available for study.

A fundamental question involved in these studies is whether developmental rate, on which racial size depends, is genetically determined by genes borne in chromosomes or by plasmatic differences in the gametes. Regarding this question information is being sought in genetic experiments in the crossing of the large and small races and back-crossing the F_1 hybrids with each parent race. The evidence so far is negative as regards any association between known genes and size characters, but the experiments are being continued in order to make their outcome more certain, both because of the fundamental importance of the questions involved and of the fact that the study of plant material has yielded evidence seemingly, but perhaps only seemingly, at variance with our own.

An essential requirement for the successful conduct of quantitative studies of the sort just mentioned is adequate equipment and technique for rearing large numbers of individuals from parents of a particular genetic constitution with a minimum of loss and for keeping them in a state of health until adult size is attained. Much time has been spent in the past year experimenting with different types of hutches and rations with the objective mentioned in view. As a result we have about doubled our accommodations for rabbits and have installed all metal cages with floors of galvanized wire cloth which favor a lessened mortality of the young and reduce the incidence of disease. A modified ration and an improved device for keeping the drinking water free from contamination have also been adopted.

The experiments with rex rabbits have been practically concluded. A continued study is being made of the linkage relation of yellow fat to albino allelomorphs. An interesting new mutation of the coat of rabbits "furless" discovered by Professor John Hammond of Cambridge, England, is being studied with foundation stock kindly supplied by Professor Hammond. A race of rabbits with peculiar blood group relations kindly supplied by Dr. Landsteiner of the Rockefeller Institute is being propagated and studied in cooperation with Dr. Clyde E. Keeler, who is continuing his studies of linkage relations among the known mutations of mice. Dr. Keeler has prepared a monographic manual on mouse genetics and the writer one on the genetics of domestic rabbits which are being published by The Harvard University Press. It is hoped that these publications will be useful to other investigators as well as to those interested in the propagation of these animals for laboratory or other uses. The writer has also prepared for publication a fourth edition of the book *Genetics and Eugenics* which makes more widely available the results contained in technical publications on the work accomplished as research associate in past years.

Dr. George Snell has continued at Dartmouth College studies of the dwarf race of mice mentioned in my last report as discovered by him, as well as of other problems of mouse genetics.

Mr. Paul B. Sawin has brought to this laboratory a colony of rabbits collected by him for the study of certain genetic problems of economic as well as of scientific interest. He is engaged in the experimental study of these problems. Mr. N. F. Waters is studying and preparing for publication an extensive series of observations on size inheritance in poultry made by him and others at the Rhode Island Agricultural Experiment Station. This he is permitted to do under a cooperative arrangement with the Station authorities.

Harvey, E. Newton, Princeton University, Princeton, N. J. *Researches on the luminescence of Cypridina hilgendorfii of Japan.*

Sixteen half-liter bottles of dried Cypridinas were received as a result of last summer's collecting in Japan, but only two of them contained well-dried luminous material, so the full program of isolation of the photogenic substances could not be carried out. Collecting is being continued under the direction of Dr. C. Ishikawa of Tokio. The research was directed along two lines: (1) Production of antibodies for luciferin and luciferase; (2) Analysis of the decay curves of very rapid luminescences by photoelectric cell with amplification and string galvanometer.

It must be recalled that luminescence in *Cypridina* is connected with the interaction of two substances, luciferin and luciferase, which can be separated in impure condition and which have definite chemical and physical properties. Dissolved oxygen is necessary for the luminescent reaction which can be represented as follows:

$$\text{luciferin (LH}_2) + \tfrac{1}{2}\,O_2 \overset{\text{luciferase}}{=} \text{oxyluciferin (L)} + H_2O + \text{heat}$$

The heat of this reaction represents available energy which can excite luciferase molecules to luminesce. Luciferase therefore plays two rôles: (1) That of supplying excitable molecules which emit the light. (2) That of catalyst for the oxidation of luciferin, which is an oxidative dehydrogenation, and the oxyluciferin can be reduced to luciferin again by various methods of hydrogenation.

(1) *Production of Antibodies for Cypridina Luciferin and Luciferase*—When extracts of luciferase are injected at intervals of 2 to 5 days into the blood of rabbits, an antibody is produced which is recognized as follows: (1) Blood of such immune rabbits when mixed with luciferase prevents the luminescence of mixtures of luciferase and luciferin, whereas normal rabbit blood does not influence the luminescence. (2) Luciferase injected into the blood of normal rabbits can be recognized for over 10 hours, whereas if injected into immune rabbits, the luciferase disappears in less than 2 hours. The antiluciferase is not destroyed at 56° to 61° C. for 30 minutes, but is destroyed at 71° for 30 minutes, and at 95° for 5 minutes. Normal rabbit serum does not restore the activity of the immune body and no indication that complement is necessary for the action of antiluciferase was found.

On the other hand, all attempts to produce an antiluciferin failed.

The results suggest that luciferase is a protein or associated with protein, whereas luciferin is not an antigenic protein.

(2) *The Decay Curves of Rapid Luminescences*—The duration of *Cypridina* luminescence depends on the relative proportions of luciferin and luciferase, since the latter is a catalyst which accelerates the reaction in proportion to its concentration. Decay curves of luminescence can be studied by direct photometric comparison or by allowing the light to affect a revolving photographic film, when the duration is of the order of minutes, but for the recording of luminescent flashes of a few seconds duration the photoelectric cell with amplification and a string galvanometer are necessary and have worked perfectly in the present investigation, which has disclosed the following points.

When the ratio of luciferin to luciferase is less than five, the decay is strictly logarithmic, *i.e.* log light intensity plotted against time gives a straight line throughout the reaction; when the ratio of luciferin to luciferase is greater than five there is a deviation from the straight line plot at the start, the "initial flash," which is a reality, unconnected with mixing the solutions. Where the ratio of luciferin to luciferase is very high the "initial flash" continues for some time, *i.e.* the log intensity against time plot is no longer straight but concave to the time axis throughout. These deviations are probably connected with adsorption of luciferin on luciferase surfaces.

The slope of the log intensity against time plot measures the velocity constant (if we assume luminescence intensity is a measure of the velocity of oxidation of luciferin) and is proportional to the luciferase concentration for rapid luminescences. With constant luciferase, the slope is the same, irrespective of the proportions of luciferin and its oxidation product, oxyluciferin, but varies with the total concentration of luciferin (LH_2) + oxyluciferin (L) in such manner that, for certain ranges, slope $= k \frac{1}{\sqrt{LH_2 + L}}$. This suggests that only the luciferin adsorbed on luciferase is activated to react and that more is adsorbed the lower its concentration. In other words the adsorption equilibrium between luciferin and luciferase and oxyluciferin and luciferase is the same and is expressed by:—amount adsorbed $= K(L + LH_2)^{\frac{1}{2}}$.

Mann, Albert, Washington, District of Columbia. *Continuation of investigations and preparation for publication of results of work on Diatomaceæ.* (For previous reports see Year Books Nos. 18–28.)

The diatom work for the past year includes several large investigations and many small ones, in addition to the two major items which have been in progress for several years. Of the latter the work at Woods Hole, Massachusetts, is now ending its tenth consecutive season. Its objective is to compile a complete diatom flora of this representative locality of our Atlantic Coast which shall serve as a work of reference for future diatom study in coastal waters from Maine to Jacksonville, Florida. It will also show the annual fluctuations of the genera and species native to this area. Such a report is much needed and has never before been undertaken. The results of this work are being prepared for publication. Type specimens of each species found are being mounted and will be kept for reference in the National Museum.

Incidental with the foregoing, experiments are in progress in testing the possibility of planting masses of living diatoms and other minute organisms that supply fish-food in barren parts of the coast, so as to increase their fertility. This is still too incomplete to indicate the outcome, but the matter involved is an important question in fish culture. A recent letter from India, referred to further on, will make this evident.

The second item carried forward annually is the work at the Dry Tortugas laboratory. Two weeks were spent there collecting material for laboratory study, chiefly at fixed stations, so that each year's collections can be compared with those of other years. The new growth of diatoms on terracotta tiles, set in different places and marked by buoys, to indicate the most prevalent species each year was also arranged for. The work was begun at the opening of the laboratory, about June first.

Numerous diatom identifications, several diatom photographs and seven diatom mounts were made for Mr. Frederick Adams of Mexico City.

Several abstracts of French and German diatom publications were made for the "Biological Abstracts" Committee.

Directions for collecting marine diatom material and some diatom literature were sent to Captain W. A. Robinson at Tahiti at the request of Captain J. P. Ault. His letter was written the day before his tragic death at Apia, Samoa.

A report was made to Martin Burkenroad of Tulane University on diatom material collected in the vicinity of New Orleans.

An extensive report on the plankton diatoms of Monterey Bay, California, was made for Dr. H. B. Bigelow of Harvard University, as a contribution to a biological report of that locality.

A diatom exhibit for the annual Exhibition of the Carnegie Institution last December was prepared; the subject, The Artistry of the Diatoms, was illustrated by 94 wall photographs and groups of diatoms under 10 microscopes. An illustrated report of the exhibit was prepared, published and widely distributed in this country and in Europe. It has been extensively republished. The publication was the work of Dr. Frank Bunker, editor of the Institution.

Some assistance was given and diatom photographs supplied for a book on the *Properties and Uses of Diatomaceous Earths,* published in the Chemical Monograph Series.

A new method of blocking out undesirable backgrounds of scientific negatives by the use of ruby-red cellophane was worked out and a descriptive article published in Science.

Several conferences were held with David S. Keely, head of the American Diatom Co., on the quality of new diatom beds being opened out along the Rappahannock River in Virginia and the Patuxent River in Maryland.

Collecting equipment was prepared for the Gifford Pinchot Expedition in the South Pacific Ocean.

A consultation by appointment was held with Mr. Miller of the Johns-Manville Corporation on microscopic tests of the quality of diatomaceous earths.

Bottles, collecting directions, etc., were sent to Mr. Breder of the New York Aquarium for use on an expedition to the Bahamas.

Samples of diatom gatherings made on the last voyage of the SS. *Carnegie* were selected and their preparation for study was begun. They promise to be very rich. Six samples of cleaned diatoms from the Philippine Islands were sent to a preparer of diatom mounts at the request of the British Museum.

Four bottles of cleaned diatoms were sent to D. P. Fuge, Shipley, England, and one to S. Chaffers, University of Manchester, England.

Diatom information and photos were sent to M. N. Watt, University of Otage, Dunedin, New Zealand.

Two dredgings taken southeast of Newfoundland, submitted by Dr. E. M. Kindle, Canadian Geological Survey, were examined and a report made.

An appointment was made with Edward Hopkins of the Department of Public Works, Baltimore, and questions of contamination of the city water supply by diatoms were discussed.

Dr. Parker Trask, investigating oil production in connection with the Rockefeller Foundation, called for a consultation on marine diatom sedimentation now going on.

A short report on diatom paleobotany was prepared for the Committee on Paleobotany of the National Research Council.

Fifty diatom lantern-slides were prepared for George Washington University at the request of Dr. R. F. Griggs, Professor of Botany.

Seventy-one samples collected by the Geophysical Laboratory of the Institution in the hot spring areas of Yellowstone Park were examined, a full list of the diatoms in each sample and their relative frequency was made, and the question of diatoms living in water of very high temperature was carefully considered. No evidence was found of diatoms living in water above 60° C. The abundant presence of dead diatoms in some very hot springs brought up some problems unsolvable by means of the material and data supplied, and therefore further collections will be made this Summer.

A letter was received about June first from George Scotland, Sidapur, South India, presenting a sinister problem. It stated that the sardines had suddenly left the west coast of India and were appearing in great numbers in the Persian Gulf. It stated this was causing much destitution among the people living in districts along the west coast. It inquired if restocking the water near shore in the deserted area would be likely to bring about a return of the fish. As helpful a letter as the circumstances made possible was sent to Mr. Scotland. This being in line with our restocking experiments at Woods Hole gives added interest to the communication.

A sample of gray marshy soil was brought to the laboratory by L. W. Stephenson of the Geological Survey. Information on the character of any diatoms contained in the material was desired and an opinion on the origin of the deposit, whether an artificial filling-in or a normal local deposit. Its bearing is on a controversy between the Government and a private corporation as to the title to certain accrued lands along the Potomac River, Virginia side.

Morgan, T. H., C. B. Bridges and Jack Schultz, California Institute of Technology, Pasadena, California. *The constitution of the germinal material in relation to heredity.* (For previous reports see Year Books Nos. 15–28.)

The following observations bear on the properties of the genes of *Drosophila:* their mutations, their behavior at synapsis and during the maturation process, and their effects on development.

Minute-n has been made the basis, as described in the last report, of a procedure that was expected to give, in rare cases, mosaic flies in which the patch was not of the usual male piebald type but was haploid and female. The experiment was planned to supply evidence as to whether these special cases represent true haploid tissue, and as to the femaleness of this tissue. During the past year two specimens, in addition to the three previously recorded, have been found. One of these came from the mating of a Mn/+, Cy/Bl, Sb/H mother and a $y^2w^esn^3$, b sp, h father—the procedure that should give the best result. This fly had a left side and the entire abdomen of the constitution: Mn/$y^2w^esn^3$, Cy/b sp, H/h. Hence it showed Mn, Cy and H and was female. The right side of the head and thorax showed $y^2w^esn^3$, b sp and h, all of these being recessives and representing the three major chromosomes X, II and III. These characters are definite, sharp and easily recognizable. The fly was exceptionally vigorous and normal in appearance. That the mosaic tissue was haploid is shown by the decrease in cell-size, by the smaller size of the eye-facets and of the wing as compared with the normal. Further, the dominants carried by the maternal chromosomes have disappeared, and their recessive allelomorphs in the paternal set are manifested in the mosaic tissue. Moreover, the number of branches in the arista, which is decreased to 8 in the triploid, is increased from 9 on the diploid side of the mosaic to 11 on the haploid side. That the sex of this haploid portion was female is shown by the eosin eye color, which, pinkish yellow in the male, displayed here its typical yellowish-pink female color. More important, the infallible index afforded by the sex combs was available, since both fore-legs were included in the mosaic region and showed no sex combs. The other case came from the mating of a Mn/+ female and a y^2w^e sn^3 b sp h male. The right side was wild type. The left side of the thorax showed a large patch in which the paternal recessives y^2 sn^3, b sp, and h could be seen. Since the head was not included, the eye color eosin did not appear. Again the cell-size was clearly smaller, resulting in a dwarfed and malformed wing, and small bristles in the haploid region. Both fore-legs were included and both were female without sex combs. These two mosaics supplement the previous three and establish beyond doubt that these examples represent true haploid tissue and that the sex of the haploid is female. The theoretical importance of this evidence in connection with the theory of genic balance has already been emphasized in the previous report.

For in the right end of the second chromosome at least four deficiencies have been found and also two or three duplications. These give interesting mutual neutralizations of each other's effects. The neutralizations may be complete, *e.g.*, when the duplication is longer than the deficiency, as PIII is longer than Px, or incomplete, as, reciprocally, the Px deficiency is shorter than the PIII duplication and does not neutralize all of the effects of PIII. This situation and other considerations have made it imperative to have an accurate map of the normal right end of the second chromosome. Briefly, the tentative new localizations are: Iɪɪax, about 0.1 to left of speck; lanceolate and lanceolate^2, about 0.2 to left of speck; purpleoid, about 0.3 to left of speck; abbreviated, about 0.5 to left of speck. A lethal present in "CyR" has been localized, within a section extending from between morula and speck to the right end of the chromosome, by the fact that it is lethal with Plexate-deficiency. The dominant mutant Plum eye color, discovered by Muller, is suppressed by PIII, showing that its locus lies within the section from plexus to the right end.

The second-chromosome recessive lethal that was found first (lethal-IIa) has its locus between black and curved. In 1918 the stock of Iɪɪa became contaminated, and in the attempt to rescue it a stock resulted that was thought not to have Iɪɪa but to have a new lethal, Iɪɪax, whose locus is far to the right of curved. In this new stock the flies die at a definite early larval stage, and the cultures show multitudes of these 1.5-mm. larvæ crawling on the walls. More exact determination of the locus puts it at about 0.1 unit to the left of speck. In trying to obtain a Iɪɪax sp double recessive, a stock was also obtained that lacks Iɪɪax, and yet has a lethal, which turns out to be the original Iɪɪa, as nearly as can be judged by the location. But this lethal is erratic, in some cultures giving complete mortality of the homozygote, and in others allowing some homozygotes to live, occasionally to 50 per cent of the expected frequency. It seems probable that the present improved culture conditions enable what formerly behaved as a complete lethal to emerge in a fair proportion of the individuals. In a high proportion of the surviving homozygous IIa flies the dorsal abdominal bands show incomplete closure in the midline. The two lethals in combination give curious effects both upon viability and linkage and are under investigation.

The mutant pink-wing, which is characterized by two apparently unrelated effects, *viz*, a pink eye color and a shorter wing that is often crumpled, was found in 1918 by Lancefield, and rediscovered by Sturtevant in 1919 and by Bridges in 1920. In the "current maps" published in 1921 the locus is given as 13 to the right of Star, a location based on the data of Bridges. This location is wrong, although it agrees with the location pink wing would appear to have if a CIIL were present. In 1924 Bridges found an allelomorph called light, and the locus was apparently about 6 units to the left of L^2 and was given as 64± in the map in Bibliographica Genetica, vol. II, page 92. This location is also wrong, for the light stock has been found to carry a CIIR. During the past year Bridges found a third allelomorph, $p\text{-}w^8$, and tests with it gave a locus just to the right of Bristle. Much more accurate determinations were made by A. de Zulueta last spring during his stay at California Institute of Technology. He used the light allelomorph, freed from its crossing-over suppressor, and found the locus to be about 0.3 to the right of Bristle, which is 0.2 to the right of purple. The locus of pink wing is therefore at about 55.0.

During the last two years an improved culture medium has been used. Its composition is roughly: water, 75.0; cornmeal, 10.0; molasses, 13.5; agar, 1.5.

Improvements in handling of the flies and cultures have also been made. In consequence of this change some types of flies that were too inviable to live at all under the old conditions now give small percentages of viable individuals. Such a case is offered by lethal-IIa, referred to above. Also dwarf flies survive in greater numbers. Homozygous Curly is ordinarily lethal and the rare survivors are dwarfs, but during the last year homozygous Cy flies of nearly normal size and fairly good viability were secured. Under these improved conditions other dwarf mutations appear more often. One clean-cut dwarf has been located in the third chromosome. There is also a giant race in which the percentage of larvæ that grow to giant size and emerge as giant adults is dependent upon the richness and abundance of food. Such is giant-2, found by Gabritschevsky. During the past year another such giant, giant-3, has been found, with a locus in the second chromosome near black. Another giant, giant-4, has its locus near dumpy not far from the left end of the second chromosome. Giant-4 is not dependent upon cultural conditions for complete development to giant size, but is dependent upon good conditions for viability of the giant. Hence under poor conditions giant-4 acts like a lethal. Several other giant flies have been found, two of which were found not to reappear in F_2. This does not necessarily mean that the giant character was purely environmental but may mean that the percentage transformation was so low that none were found under the special conditions in those cultures. It is to be noted that all four giants thus far found have been remarkably similar or perhaps identical in body size. This standardization of size may mean that all behave like giant-2, in which it was found that there is an extra moult and that the larva that is to become a giant feeds about four days longer, hence differs from the wild by a definite jump in size.

In a cross between a Star female and a Curly male it was observed that about a third of the flies that were both Star and Curly had eyes with a strongly developed Star character. The enhanced Star eye was only about one fourth the area of the usual Star eye, and the facets had partly run together as in lozenge or in glass. Other flies in the culture were all normal in character, hence the enhancer appears as a specific modifier of Star. It is dominant, as outcrosses show, but not lethal when homozygous. The enhancer is carried in the Curly second chromosome, where it arose by mutation in the father of the culture where it was first detected. The mutation occurred early enough in the development of his gonads so that 30 per cent of the sperm carried it while the rest did not. It enhances S^2, an allelomorph of S, to the same extent that it enhances Star itself. Since the enhancer arose in the Curly chromosome, which has an inversion in the left limb and an inversion in the right limb, it was not easy to determine the locus within the second chromosome. But by making the flies homozygous for the inversions it was found that the enhancer lies 2.5 units to the right of Curly and 1.5 to the left of black. This is the region, between Curly and black, where the inversion ends. It is therefore unknown whether the enhancer lies in the normal or in the inverted part of the chromosome. A striking peculiarity of the enhanced Star flies is that a small proportion of them are giants. These giants (giant-3) occur at the very end of the counts of a culture and are predominantly females. It is suspected that the giant size is another expression of the interaction of Star and the enhancer, but possibly it is due to a distinct factor closely linked to the enhancer.

A suppressor of purple has been found that differs in certain respects from one reported recently by Stern. Both turned up in the black purple stock. In homozygous form each changes homozygous purple (a second-chromosome recessive eye color) into the red eye color of the wild type. The locus of each is in the right limb of the third chromosome. The locus of Stern's suppressor is apparently just to the left of Hairless, but in his stock a strong crossing-over reducer is present with the suppressor. In the newer stock no crossing-over suppressor is present and the locus is considerably to the right of Hairless, about at rough. In both, the flies are poorly viable, but in Stern's much more so. Both are completely male-sterile, but while Stern's flies are completely sterile in the female as well, the females of the later suppressor are fairly fertile.

In the last report some experiments were described in which the possible transmission of injury to the eyes with its secondary effects on the Malphigian tubules was studied. The complete report of this work has since been published in the American Naturalist.

Several earlier reports have described experiments with a low female producing stock derived from broken X females. Several of these stocks have been continued through the year. Some now give normal ratios, others continue to produce low female ratios. The former have been tested in several ways to discover whether a modifier is present in the X chromosome that nullifies the factor for changing the sex ratio. No such modifier was detected—if present it must be very closely linked to the low producing gene. In order to discover whether the stock that has reverted to the normal ratio still contains flies that can be brought back through selection to the low female condition, several experiments have been made and are still underway. Conversely stocks still giving low ratios have been "spread out" to see whether reversion takes place on a sufficient scale to permit detection.

In an experiment in which larvæ were kept in an atmosphere of pure oxygen it was found that after three or four days the young larvæ cease growing and die, both in the oxygen or if removed to the air. A microscopic examination of these larvæ shows that after the second or third moult the main tracheal tubes degenerate, hence probably the death of the larvæ. The work is being continued to determine whether in oxygen the mutation rate is affected and whether from larvæ or adults kept in an atmosphere of pure oxygen the kinds of mutations are changed and whether reversal of recessive mutant characters takes place more frequently.

A study of the effects of X-rays on *D. obscura* has been made. Males and females of this species were rayed, the males serving as material for two different dosages. The F_1 from the outcross of the treated males showed a low ratio of females to males. In the experiment with the lower dosage, this was 0.57; with the heavier dosage, the ratio was depressed to 0.40, while in the controls it was 1.16. A slight effect of this sort has been obtained in *D. melanogaster* by Muller, and interpreted as due to dominant lethals in the X. There are other possibilities, all involving some change in the X-sperm. On any assumption of this sort, a more extreme effect should be expected in *D. obscura,* where the X chromosome contains roughly 43 per cent of the chromatin, as opposed to only 28 per cent in the *melanogaster* X.

The effect of raying was more extreme in males than in females given the same dosage. The former showed a total of 20.5 per cent abnormalities as opposed to 7.5 per cent from the females. These abnormalities include dominants detected in F_1, sex-linked recessives, males with no gonads, mosaic changes which were non-genetic, etc. Of the dominants, a large portion were Minutes, although other characters occurred. The indications are that, as among the spontaneous mutations, there may be relatively more dominants occurring in *obscura* than in *melanogaster.*

A number of stocks of special interest were obtained from the treatment—a strain which gave high non-disjunction of the X chromosomes, several crossover reducers in the X, and among the dominants detected in the F_1 from outcrosses of treated parents, three were found to be associated with translocations. Of these translocations, two involved chromosomes II and the Y, the other chromosomes II and III, with the possibility that the X might also be involved.

In one of the II-Y translocations, associated with the dominant Delta, the Y chromosome is cytologically abnormal.

In males carrying Delta with the translocation, about 3 per cent non-disjunction occurs, giving XO not-Delta males and XXY Delta females; since both duplication and deficiency die in this translocation, all the regular males are Delta, the females not-Delta. In the XXY females containing the translocation, Delta has been located, approximately 30 units from Bare, the dominant bristle-mutant found by Sturtevant to be in this chromosome.

The XO males from Delta are sterile but otherwise normal. In the maturation divisions, instead of lagging slightly on the spindle, as is normal, the X frequently goes to the pole before the autosomes, indicating that the speed of progression of chromosomes to the poles is influenced by the presence of a homologue on the spindle.

From crosses of Delta males to females from Lancefield's Race B, XO hybrid males have been obtained. These have small testes, like the XY hybrids when the cross is made in this way. This indicates that the difference in testis size between these male hybrids and those obtained from the reciprocal cross, which have large testes, is probably not due to the Y-chromosome of the A race.

One of the sex-linked mutants found, bubble-2, is an allelomorph of the bubble found in Race B by Lancefield. This has made possible a comparison between crossover values in this region in the two races and the hybrids. The results indicate that crossing over may be lower in Race A than in Race B and the hybrids; whereas Lancefield found lower values at the left end in Race B than in Race A.

A translocation in *D. melanogaster* in which both duplication and deficiency are viable and fertile was turned over for study by Dr. Th. Dobzhansky, who discovered it in one of his X-ray experiments. The translocation involves the attachment of a piece out of the middle of chromosome II, including the locus of purple, to the Y chromosome. Individuals carrying the duplication for this piece are very slightly, if at all, different from normal. The deficiency, on the other hand, produces the small bristles, rough eyes and other characteristics of Minutes. Flies heterozygous for purple and the deficiency show purple, but without any noticeable "exaggeration" effect.

Studies are in progress on crossing over of the second chromosome in this duplication, deficiency and translocation. In presence of the translocation, crossing over in the right limb is almost completely suppressed. This is also true in presence of the deficiency alone. In the flies carrying the duplication, however, crossing over is practically normal for the right limb. These facts indicate the simultaneous occurrence, with the translocation, of another crossover abnormality, probably an inverted section carried by the deficient chromosome and affecting the right limb. For the left limb, in the presence of the translocation, there is apparently a decrease, more extreme in the region of the translocation, progressively less extreme further out towards the end.

Triploids have been obtained carrying both translocation and deficiency. In those carrying the translocation the deficient chromosome almost always goes into the diploid egg, which indicates, as might be expected, very little synapsis between that chromosome and the two normal homologues. The total percentage of diploid eggs produced in such cultures is normal, but the ratio of 3N to intersexes is higher than normal.

Triploids carrying the deficiency and two doses of purple show purple, but none of the dominant characters of the deficiency. In these triploids, crossing over between the deficient and the two normal chromosomes has been studied. In the right limb, no crossing over occurs, as in the diploid. In the left limb, there is decreased crossing over compared with that in the normal triploid.

An allelomorph of Bridges' MI deficiency was found by Schultz some years ago, and located at 0.3 to the right of plexus. MI^2 lacks the arc plexus deficiency and female sterility characteristics of MI, although it is lethal with M-I and behaves as does the latter with the duplication and deficiency of the Pale-translocation. Crossing over in chromosome II, in MI^2 females, has been found to be substantially normal, except around the right end, where it is reduced.

Comparison may be made between the effects of two "deficiencies" plus a normal allelomorph in those cases where the extra allelomorph is obtained through triploidy of the whole set, or through a duplication. This test for Minute-I^2 and the PIII duplication shows that in both cases such a fly dies. This is, however, in contradiction to the case in which one of the deficient allelomorphs is Pale-II, the other MI^2 and the normal allelomorph is carried by PIII. In this case the fly lives and is Minute. Similar results occur with the Plexate deficiency. These results may indicate a difference between the effects, on the properties of the same locus, of longer and shorter deficiencies; or it may be necessary to revise the interpretation.

The complete crossover suppressor reported by Gowen produces triploids, and hence in combination with mutant changes that are themselves viable or fertile only in females, may be used to produce triploids carrying these changes—stocks otherwise unobtainable. During the course of such an experiment, non-disjunction of the sex chromosomes was followed in such a way that equationals could be detected. If the non-disjunction occurred at both equational and reductional divisions (a real distinction in this case, since no crossing over occurs) one-third of the exceptions should be equational. No equational exceptions were found, which means that the non-disjunction occurs only at the reduction division. This is to be expected, if the assumption is made that the reduction of crossing over in this case is due to a failure of synapsis. There should be non-disjunction of the chromosomes at the reduction division on this assumption, but the equational division should then proceed normally, with the results as found.

A series of experiments has been carried out in collaboration with Dr. Helen Redfield to determine whether non-homologous chromosomes behave as independent entities in crossing over. The first experiment involved backcrosses of females in which chromosomes I, II, and III were marked—these females had the composition $\frac{w^e\ sn}{+}\ \frac{b\ sp}{+}\ \frac{h}{H^2}$. The data show definitely that for the particular regions involved, crossing over in one pair of chromosomes is negatively correlated with that in another pair. If crossing over occurs in one of these regions it is less likely to occur at the same time in either or both of the other two regions.

Backcrosses of females of the composition $\frac{vg^3\quad}{B}\ \frac{D\quad H}{Sb}$ similarly showed that for the new regions, covered by this cross, crossing over in I is negatively correlated with crossing over in III. If this relation holds we might expect that the inhibition of crossing over in one of these chromosomes would tend to increase it in the other. This possibility was tested by crosses of females containing a crossover reducer for chromosome I. These females, $\frac{\mathrm{ClB}}{\mathrm{v}\quad \mathrm{g}^{3}}\frac{\mathrm{D}\quad \mathrm{H}}{\mathrm{Sb}}$, give crossover values for III which are, as expected, higher than those obtained from females without the reducer.

A new experiment involved backcrosses of females of the composition $\frac{\mathrm{w}^{e}}{\mathrm{v}}\frac{\mathrm{Bl}}{\mathrm{L}^{c}}\frac{\mathrm{D}}{\mathrm{H}^{2}}$. These crosses show a negative correlation between crossing over in $\mathrm{w}^{e} - \mathrm{v}$ and in $\mathrm{D} - \mathrm{H}^{2}$. However, crossing over in the region $\mathrm{Bl} - \mathrm{L}^{c}$ in II shows no correlation with (or may indeed show a positive correlation with) crossing over in the region $\mathrm{w}^{e} - \mathrm{v}$ in I or the region $\mathrm{D} - \mathrm{H}^{2}$ in III. These experiments are being extended. In the meantime it may be stated that crossing over in one pair of chromosomes is not necessarily independent of crossing over in another pair, and that the type of correlation observed depends upon the particular chromosome regions involved.

The many eye-color mutants of *Drosophila* furnish material for the study of problems in the physiology of gene expression. As a first step, the pigments concerned have been investigated by means of spectrophotometric measurements of their absorption curves.

In the twenty eye-color types so far studied three water-soluble pigments—red, yellow and brown—have been found. The red pigment, in acid solution, shows an absorption maximum at $\lambda 470$, which in alkaline solution shifts to $\lambda 510$. The yellow pigment, which has its maximum of absorption at $\lambda 410$ in acid solution, increases its absorption in alkaline solution, where the maximum shifts to $\lambda 430$. The brown pigment shows an absorption curve with its maximum probably in the near ultra violet and with the same shape in acid as in alkaline solution.

Purification of the pigments has been attempted by various techniques. No preparations have been obtained so far that are free of amino acids. Out of mixtures of the different pigments, it has been possible partially to separate them from each other, using the absorption curves as a criterion of separation.

A chemical relation between the three pigments is indicated by the fact that after certain treatments, the red and yellow pigments are changed so that their absorption curves in acid and alkaline solutions are like those of the brown pigment under like conditions.

The different eye-color mutants may be grouped into four general classes, according to the pigments they contain. Three of these classes correspond to the three pigments, each containing one pigment in high concentration compared with the others. The fourth group contains those types in which mixtures of the three pigments are present. Genetic combinations have been made of mutants from different groups, and the pigments present in the combinations studied, to obtain data on the interaction effects.

Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts. *Study of East African mountain fauna.*

The expenses of this study have been provided in part by a grant from the Carnegie Corporation of New York to the Carnegie Institution of Washington, and the following is a preliminary report on the subject.

Arthur Loveridge of the Museum of Comparative Zoology, Cambridge, Massachusetts, assisted by a grant from the Carnegie Institution, left on August 31, 1929, for East Africa with the object of endeavoring to trace the probable route by which the present reptile-amphibian fauna of the Uluguru Mountains reached that range. The expedition was in continuation of work commenced in 1926–7. On the present occasion an exhaustive search was made for reptiles and amphibians in the principal ranges to the south and west of the Uluguru. This included the Uzungwe, Ubena, Ukinga, Rungwe and Poroto Mountains. It may be confidently stated that the results point clearly to the Uluguru fauna, with its markedly West African relationships, having been derived through the Nguru and Usambara Mountains and not along a southwestern route; in fact the reptile-amphibian fauna of the southern highlands (Uzungwe, etc.) has marked South African relationships and only a very few of its mountain-forest forms are common to the Uluguru range.

Much information was gathered on the bionomics of the creatures collected, some of the notes being distinctly of agricultural importance, as, for example, that the small and harmless snake *Duberria lutrix,* usually destroyed on sight, lives almost exclusively on slugs, yet one settler informed Mr. Loveridge that his boys had killed over ninety in a morning when clearing land for coffee planting!

Incidental to these studies over a hundred species of mammals were collected, 237 species of birds, 56 kinds of snakes, 50 of lizards, 18 of chameleons, 6 of turtles, 2 of cæcilians and 52 of frogs and toads. The trip extended over two rainy seasons, the "big rains" being the heaviest recorded for forty years.

Sumner, F. B., Scripps Institution of Oceanography, La Jolla, California. *Continuation of ecological and genetical studies with Peromyscus.* (For previous reports see Year Books Nos. 27 and 28.)

Work during the past year has been of two sorts: (1) completion of a report upon subspecific hybrids within the species *Peromyscus polionotus;* (2) the completion of a series of preliminary experiments upon specific differences in water consumption between *Peromyscus maniculatus* and *P. eremicus.*

SUBSPECIFIC HYBRIDIZATION

The first of these tasks concludes the most extensive single line of investigation which I have thus far conducted with *Peromyscus.* The material used was exceptionally favorable, in that very striking genetic differences were shown between geographic races which occurred in rather close proximity to one another, while an interesting parallel was evident between the geographic gradient and that of coat color. Furthermore, Mendelian segregation, following crosses, was so obvious that any reasonable doubts regarding a factorial interpretation of certain subspecific differences became untenable.

The parent stock for these experiments was obtained in Florida and Alabama during the summer of 1924, and descendants of this stock, mainly hybrids, were reared until 1927. The prolonged delay in the preparation of this report has been due to the time required for the measurements of the pelages and skeletons, and particularly for the statistical treatment of the data thus obtained. The results of this research may best be indicated by quoting the summary from a paper to be published in the Journal of Genetics. It will, however, be impossible to discuss the significance of these facts at any length.

(1) The geographic races of mice, chiefly here considered, differ from one another rather strikingly in the quantity and distribution of pigments in the hair and skin, and also differ, though less strikingly, in certain details of bodily proportions. In total size, these races are approximately equal. In the case of the single inter-specific cross, the two species differ considerably in general size, as well as displaying, in an even higher degree, all of the other classes of differences just mentioned.

(2) The pigmental characters of the geographic races bear definite relations to certain environmental gradients. The linear measurements of body parts, while exhibiting local differences, show no such constant relations.

(3) The mean racial differences in both linear and colorimetric characters are entirely genetic. Stocks of different races fail to converge when reared for a number of generations in a common environment.

(4) Individual differences within a single race are partly genetic, as appears from coefficients of correlation between parents and offspring, or between other groups of related individuals. These individual differences relate to the same bodily "characters" as do the racial differences.

(5) Individual differences are, however, to a considerable extent non-genetic, as is shown by the relatively low values of most of these parent-offspring correlations, and by the observed fact that some characters, particularly the length of certain members, are demonstrably affected by environmental conditions.

(6) As regards the degree of distinctness which is shown by two races subjected to hybridization, the characters herein dealt with fall under three heads: (*a*) characters which are invariably present in full measure in one race and invariably absent in another (*e.g.*, tail stripe, and pigmentation at base of ventral hair, in the *leucocephalus-polionotus* cross; pigmentation of ventral hair in the *polionotus-albifrons* cross); (*b*) characters which are present in both races, but which vary so widely in degree that there is no overlapping of the distribution "polygons" for the various values (*e.g.*, red and colored area in all three of the racial crosses); (*c*) characters in which the two races differ in respect to the mean values shown, but in which there is a more or less broad overlap of the individual values (*e.g.*, the index of saturation, tail and foot length and bone measurements, in all three crosses).

(7) In respect to all of these racial differences, both linear and colorimetric, the first as well as the later hybrid generations show an intermediate condition. For most characters, the mean value in the F_1 and F_2 generations is approximately midway between the parental means, *i.e.*, there is no appreciable dominance.

(8) Dominance is strikingly shown, however, in the case of one character, tail stripe. Lack of tail stripe is dominant, though incompletely so, over its presence, this phenomenon being clearly illustrated in two inter-

racial crosses and in one inter-specific cross. This dominance is of the "fluctuating" type, there being an enormous range of variability in the first hybrid generation (at least in the subspecific crosses).

(9) Dominance is less strikingly shown in the case of another pigmental character, relative pallor or darkness of the pelage, represented by the value for "red" (R) in the preceding pages. A dark pelage (indicated by a low value for R) is incompletely dominant over a paler one.

(10) The facts cited in the two preceding paragraphs are rather unexpected, inasmuch as the degree of development of the tail stripe is negatively correlated with "red" (*i.e., positively* correlated with depth of pigmentation). Yet presence of tail stripe is recessive, while depth of pigmentation tends to be dominant.

(11) In the case of both of these characters which display a partial dominance, there is a shifting of the mean in the recessive direction in the F_2 generation, as compared with the F_1.

(12) In no case does our evidence indicate that a racial difference in respect to any distinguishable character is dependent upon a single pair of Mendelian allelomorphs. This is evident from an inspection of the graphs. In the one instance in which we have the appearance of a secondary mode in the F_2 generation, it was shown that a one-factor interpretation was quite improbable. Likewise, the seeming presence of a single factor having visible effects upon the tail stripe, in the interspecific cross is very doubtfully open to such an interpretation.

(13) That genetic segregation occurs, none the less, in respect to one important class of characters at least, is conspicuously shown by the graphs for the various measurements of the intensity and extensity of pigmentation, as well as by the relative magnitudes of the standard deviations for the F_1 and F_2 hybrid generations. It is most conspicuous in the widest of these crosses (*leucocephalus-polionotus*), though quite pronounced in the *leucocephalus-albifrons* cross. The two back-cross generations show rather erratic relations in this respect.

(14) As regards the linear measurements of body parts, there is, on the contrary, little or no evidence of segregation. The standard deviations of the F_1 and F_2 generations have been compared for seven sets of linear measurements (tail, foot, ear, certain bones), considered separately for the two sexes. In the *leucocephalus-albifrons* cross, the F_2 figure is actually more often smaller than larger. This is true both for the "actual" and the "corrected" values. In the *leucocephalus-polionotus* cross, on the other hand, in which the differences between the parent races are much more pronounced, the F_2 figure ("actual") is larger than the F_1 in 11 cases out of 14, though this proportion falls to 8 out of 12, when "corrected" values are considered.[1] It must be said, however, that the differences, taken singly, are in most cases trivial.

(15) The number of genetic factors commonly concerned in any single character difference is probably considerable. Estimates of these numbers are obtained by various methods of calculation. It is likely that the lowest of these are erroneous.

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[1] The latter are not given for skull breadth, hence the difference in total number.

(16) In the narrower *leucocephalus-albifrons* cross, several individuals in an F_2 generation of 74 reach or surpass the mean of one or the other parent race in respect to the value of colored area or of red. Even in the wider *leucocephalus-polionotus* cross, two or three individuals out of 106 reach the mean of each parent race in respect to the value of colored area, though not of red. One individual, however, reaches the value of red of its own *polionotus* grandparent.

(17) If we provisionally consider those individuals which reach or surpass the mean of one parent race, with respect to a given character, as "pure" segregants for that character, and base our computations upon the F_2, and the first and second back-cross generations of the *leucocephalus-albifrons* and *leucocephalus-polionotus* crosses, respectively, we reach the following estimates. The difference between *leucocephalus* and *albifrons*, in respect to the magnitude of the colored area, is determined by about 4 factors (2 to 6), the difference in their value for red being determined by 2 to 3 factors. On the other hand, the relative magnitudes of colored area in *leucocephalus* and *polionotus* would seem to depend, according to this method of computation, upon between 3 and 4 factor differences, while the relative magnitudes of red would depend upon 3 to 5 factor differences. Similar estimates are obtained if we rank as a "pure" segregant any individual which reaches or surpasses its own particular ancestor (or ancestors) of one or another race, in respect to a given character.

(18) That most of the estimates above given are too small would seem to be indicated by a comparison of the histograms for the "grades" (7/8 *leucocephalus*) with the theoretical distribution of values in a generation of this composition.

(19) In the *leucocephalus-albifrons* cross, 15 to 18 per cent of the F_2 individuals fall within the extreme range of one or the other parent race in regard to all of the pigmental characters here considered, taken collectively. About two-thirds as great a proportion, however, fall within these limits even in the F_1 generation. In the wider *leucocephalus-polionotus* cross, on the other hand, not a single individual in either of these generations falls within the limits of *leucocephalus* for all of the pigmental characters, although three F_2 individuals fall within the limits of *polionotus*.

(20) If we seek for individuals which measure up to the "average" condition of one or another of our pure races in respect to the ensemble of pigmental characters (*i.e.*, a standard which would include a half of the population of a given pure race) we do not find a single such case in the F_2 generation of either of our two principal crosses. A number are excluded from one or the other class in the *leucocephalus-albifrons* cross, only because they fail to conform to the standard set for the index of saturation. Thus, the richness of coloration has been found to be inherited to a considerable degree independently of either the depth or the extensity of pigmentation. Five out of 58 back-cross individuals, and 9 out of 41, among the "grades," in the *leucocephalus-albifrons* cross, conform, however, to the standards set for an "average" *leucocephalus*. In the *leucocephalus-polionotus* cross, we do not meet with any cases of this sort until we reach the "grades," among which we find 11 out of 55 which may be rated as "average" *leucocephalus*.

(21) In both pure races and hybrids, the length of certain members (tail, foot, ear) is found to be positively correlated, even when the influence of general body size has been eliminated by the method of partial correlation. Longer-tailed individuals, like longer-tailed races, tend to have longer feet. There are, however, no significant differences between the hybrid generations in respect to the magnitude of these correlations.

(22) The various pigmental characters are likewise correlated with one another, both in the pure races and the hybrids, and here again intra-racial correlations are of the same sign as inter-racial ones (*e.g.*, "colored area" and "red" are negatively correlated, within each population, just as the race having the most extended colored area has the lowest value for red, and vice-versa).

(23) The last-named correlations are commonly lowest for the pure races and F_1 hybrids (lowest of all, indeed, in the latter); higher for the F_2 generation, and highest of all in the F_3 generation, derived from selected F_2 parents. The coefficients for the back-crosses are variable and scarcely more often higher than lower, in comparison with those for the F_1.

(24) These relations are, for the most part, such as might be expected, on the supposition that the characters concerned are in some way genetically connected, and that they therefore tend to segregate together. Reasons will be advanced below [not here included] for believing that these correlations are due to the diverse effects of the same genetic factors, rather than to separate factors bound together by linkage.

(25) This common genetic basis for all the various pigmental characters is not, however, absolute. There is a considerable degree of independent variability among these characters, and it may be shown that a large fraction of this independent variability is genetic. Thus, two pigmental characters may be supposed to have certain factors in common and certain ones peculiar to themselves.

(26) There is some evidence for the existence of correlations between the bodily appendages (tail and foot) and the pigmental characters, in certain of the segregating generations of hybrids, in all three crosses. The coefficients are preponderantly of the "expected" sign, on the assumption that the character differences of a subspecies should segregate together. While the considerable series of coincidences here displayed can hardly be credited to random sampling, there are circumstances which render the foregoing interpretation somewhat questionable.

Specific Differences in Water Consumption

Studies of the relative water consumption of different species and subspecies of *Peromyscus* were long ago planned as part of an inquiry into taxonomic differences in physiological characters. A highly interesting preliminary series of experiments along these lines was conducted during the past year by my assistant, Mr. Llewellyn G. Ross. A report upon these has already been prepared by Mr. Ross for publication.

The experiments indicate that *Peromyscus maniculatus sonoriensis* consumes more water per unit of body weight than *P. eremicus eremicus*, and that *P. maniculatus gambelii* consumes more than *P. eremicus fraterculus*. Thus, in each case, the representative of the species *maniculatus* consumes more than the representative of the species *eremicus* dwelling in the same territory.

These facts are of considerable possible significance, when viewed in relation to the geographic and ecologic distribution of these two species. *Peromyscus maniculatus* is a species of wide range and high local variability, covering most of the continent, under every sort of climatic conditions. It is represented on the coastal plain of Southern California and some other regions of moderate humidity by the subspecies *gambelii;* in the desert, it is represented by the subspecies *sonoriensis*. *P. eremicus,* on the other hand, is confined to arid and semi-arid portions of Mexico and the southwestern United States.

These species differ likewise in their ecological distribution. The subspecies of *P. eremicus,* whether on the desert or the coast, are more thoroughly xerophilous than are the subspecies of *maniculatus.*

In each case, groups of individuals were compared which were approximately of the same age and which had been reared from birth under identical environmental conditions. In other words, the differences which were found were hereditary. Adequate statistical technique gave strong indication that the differences were real ones, or at least were not due to random sampling.

In connection with the probable difference in water consumption between these two species of *Peromyscus,* it is interesting to note that no significant differences were detected between two subspecies within either of these species, even subspecies occupying such widely different climatic regions as do *P. maniculatus sonoriensis* and *P. m. rubidus.*

It is hoped that further tests may be made of possible taxonomic differences in the physiological characters of these mice with apparatus, some of which is already available.

CHEMISTRY

Noyes, Arthur A., California Institute of Technology, Pasadena, California. Researches upon: (1) *free energies and reduction-potentials;* (2) *structure of crystalline substances determined by X-rays;* (3) *atomic and molecular structure, theoretical;* (4) *rates of gaseous chemical reactions;* (5) *chemical reactions produced by molecules activated by radiation;* (6) *quantitative spectroscopic analysis;* (7) *band spectra and symmetry relations of polyatomic molecules;* (8) *general physics.* (For previous reports see Year Books Nos. 2–28.)

Funds supplied by the Carnegie Corporation of New York to Carnegie Institution of Washington for the support of fundamental studies in chemistry at the California Institute of Technology have enabled the following investigations to be carried out.

1. Free Energies and Reduction-Potentials

Dr. L. R. Brantley, in association with Professor A. O. Beckman, has completed and published the investigation, described in last year's report, on the equilibrium-pressures of carbon monoxide for the reaction $TiO_2 + 3\,C = TiC + 2\,CO$. It has been proved by X-ray measurements that the substances shown in this equation are present as solid phases. Within the temperature range 1278° to 1428° A, the increase in free energy and in heat-content that attend this reaction at one atmosphere pressure was found to be given by the expressions $\Delta F = 45{,}930 - 35.01\,T$ calories, and $\Delta H = 45{,}930$ calories. The equilibrium pressure is 1 atm. at 1312° A.

Mr. Albert Myers, associated with Professor Beckman, is investigating the high-temperature reaction between chromic oxide and carbon. To permit the use of larger constant-temperature furnaces than can be conveniently operated from storage batteries, a novel automatic constant-voltage regulator for alternating current has been successfully constructed, which maintains the voltage constant within 0.1 per cent.

Professor Don M. Yost has carried out and published a research on the vapor-pressure and vapor-density of selenium tetrachloride. It was found that over the range of temperatures from 100° to 230° the vapor consists entirely of chlorine and the previously unknown compound selenium dichloride. The heat of formation of the dichloride was found to be 10,780 cal. The vapor-pressures of the solid tetrachloride in millimeters of mercury are represented by the formula:

$$\log_{10} p = -\frac{0.05223 \times 73{,}990}{T} + 11.2040.$$

Professor S. Hakomori has measured the electrode-potential of metallic indium against solutions of indium chloride. The value computed for $In(s), In^{+++}$ (1 m.) was found to be +0.336 volt at 25° referred to the molal hydrogen electrode.

Mr. S. C. Woo is studying by chemical and electromotive-force methods the complex iridium chlorides with the view of determining the reduction-potential between tripositive and quadripositive iridium. Methods of preparation and analysis of the pure substances and of mixtures have been developed, and the potential measurements are now in progress.

2. Structure of Crystalline Substances determined by X-Rays

Professor Linus Pauling, with the assistance of Messrs. J. L. Hoard, M. D. Shappell, J. Sherman, and S. Weinbaum, has continued the application of his rules governing the structure of complex ionic crystals to the investigation of minerals, mainly the silicates. This has resulted in the determination of the structures of pseudobrookite, sodalite, helvite, natrolite, scapolite, cancrinite, hydrargillite, talc, pyrophyllite, kaolinite, the micas, the brittle micas, the chlorites, cadmium chloride, bixbyite, and the C-modification of the sesquioxides.

Dr. J. H. Sturdivant has completed his study of the structure of tantalite-columbite. He has also continued his work of obtaining an accurate triple Fourier-series representation of the electron distribution in crystals, and has designed and constructed an Astbury integrating alpha-ray photometer for measuring the intensities of Laue spots.

3. Atomic and Molecular Structure: Theoretical

Professor Linus Pauling has shown with the aid of the quantum mechanics that in a crystal containing molecules or complex ions with small moments of inertia about certain axes the molecules or ions may rotate freely about these axes at ordinary temperatures, and that oscillational motion about equilibrium orientations may set in only at low temperatures. The change from oscillational to rotational motion explains the frequently observed gradual transitions that are accompanied by a small heat-absorption over a range of several degrees of temperature and by a small volume-increase, but usually by no change in crystal structure. Thus such transitions have been observed with methane, the hydrogen halides, and the ammonium halides. Rotation of the alkyl ammonium ions in crystals of the alkyl ammonium halides also accounts for the previously puzzling X-ray data obtained by Hendricks, who had suggested that his observations required that the accepted staggered configuration for the aliphatic carbon chain be abandoned.

4. Rates of Gaseous Chemical Reactions

Professors H. C. Ramsperger and R. C. Tolman have continued measurements on the rate of decomposition of nitrogen pentoxide at very low pressures. A 45-liter flask was used to reduce the effect of the walls of the vessel. The use of an electrical-capacitance pressure gage made it possible to measure pressures in the range from 0.05 mm. down to 0.005 mm. with an accuracy of 1 to 2 per cent. It was found that the specific rate was only about 60 per cent of its high-pressure value at a pressure of 0.005 mm., and very nearly the high-pressure value at one of 0.05 mm. When glass tubing was placed in the reaction vessel the specific rates were considerably greater than the high-pressure constants at the lowest pressures, but at 0.05 mm. the values were nearly the same as at high pressures. It has been shown that the discordant results of other investigators at low pressures may have been due to effects of the surface. The falling off of the rate at these low pressures at last brings this unimolecular reaction roughly into agreement with a collisional theory of activation.

Professor Ramsperger has also reinvestigated the thermal decomposition of sulphuryl chloride. Rate-constants were obtained, some of which were only one-tenth as large as those previously reported in the literature (by D. F. Smith). They were, however, not reproducible, which indicated that catalysis, probably by impurities in the sample, was still present. It seems probable that in the earlier study this reaction was largely catalytic at all temperatures.

Mr. J. A. Leermakers, in association with Professor Ramsperger, is investigating the thermal decomposition of azo-amine methane ($CH_3 - N = N - NH - CH_3$). It has been found that this substance decomposes at a measurable rate at temperatures from 200° to 230° C. Good first-order constants are obtained. These are independent of the initial pressure when this is above 1 cm., but they fall off below this pressure as did those of azomethane. Experiments have been made down to 0.3 mm. The molal heat of activation is approximately 34,000 cal.

Mr. G. Waddington, in association with Professor Ramsperger, has begun a study of the thermal decomposition of phenyl methyl diimide ($C_6H_5N = N - CH_3$) in the gas phase. Preliminary experiments have shown that this substance decomposes at a measurable rate at about 330° C.

Professors W. D. Bonner and Don M. Yost have carried out and published an investigation on the gas reaction between hydrogen and iodine monochloride. Reaction-rate measurements showed that the reaction proceeds according to the equation $2\,ICl + H_2 = 2\,HCl + I_2$, and takes place at a measurable rate at temperatures just above 200°.

5 CHEMICAL REACTIONS PRODUCED BY MOLECULES ACTIVATED BY RADIATION

Mr. J. Urmston, in collaboration with Professor R. M. Badger, has been studying a photochemical reaction of iodine gas under rather special conditions. Iodine gas has been shown to consist of two types of molecule differing in their symmetry relations. One of these kinds may be activated selectively by the absorption of monochromatic light, and by allowing these molecules to react with a suitable acceptor (hexene) a partial separation of the symmetric and antisymmetric molecular types has been effected.

Professor A. O. Beckman and Dr. R. R. Wenner have completed the measurements of the quantum-yield in the decomposition of gaseous hydrazine by monochromatic radiation of wave-length 1990 Å. Hydrazine appears to decompose by two simultaneous reactions into ammonia, hydrogen, and nitrogen, since the composition of the products and the quantum-yield depend upon the pressure of the hydrazine. In the pressure range of 2 to 14 mm. of mercury, the quantum-yields vary between the approximate limits 1.0 and 1.6 molecules of hydrazine decomposed per quantum of radiation absorbed.

Working under the direction of Professor R. C. Tolman, Dr. D. B. McRae has developed a satisfactory method of measuring the reflectivity and transmissivity of photographic plates for light of different wave-lengths, under conditions of exposure which do not exceed those employed in ordinary photographic use. The method has been applied to a determination of the properties of Eastman 40 plates, using "blue," "green," "red," and "actinic" light. The results (already published) show that the reflectivity and transmissivity of these plates are practically unaffected by exposures insufficient to produce an appreciable blackening previous to development. They also show that the fraction of the light absorbed by the plate varies with wave-length in approximately the same manner as the photographic sensitivity varies with wave-length, reaching a value of 66 per cent absorption for "blue" light.

The following photochemical researches have been carried out in association with Professor R. G. Dickinson.

Mr. S. F. Ravitz has continued his investigation of the rate of the photochemical reduction of ferricyanide-ion by iodide-ion expressed by the equation: $[Fe(CN)_6]^{3-} + I^- = [Fe(CN)_6]^{4-} + \frac{1}{2}I_2$.

With green light two ferricyanide molecules were found to be reduced per quantum absorbed. It has also been shown that the reaction $Fe^{+++} + I^- = Fe^{++} + \frac{1}{2}I_2$ can by suitable choice of concentrations be made to proceed photochemically either to the right or to the left, although the activating radiation and the light-absorber (I_3^-) are kept the same. A photochemical reaction has been found to occur between gaseous ICl and H_2 with the production of I_2; and this is being studied further.

Mr. C. E. P. Jeffreys has studied the photochemical decomposition of chlorine monoxide (Cl_2O) in carbon tetrachloride solutions. There was found among the products considerable chlorine dioxide (ClO_2); and when this is taken into account, there results a much higher quantum yield (nearly 2 Cl_2O decomposed per quantum absorbed) than had been previously found for this reaction.

Dr. H. B. Wellman has constructed a photoelecrtic photometer to use in following the rate of chemical reactions. With its aid he has made preliminary measurements on the gaseous photochemical reaction: $Br_2 + CHCl_3 = HBr + CBrCl_3$. These measurements indicate that its rate (unlike that of the reaction $Br_2 + H_2 = 2HBr$) is proportional to the light-intensity.

Mr. S. Stewart West has measured the Raman spectra given by a number of sulfur compounds; and the spectra obtained from liquid sulfur dioxide have been published.

Mr. C. F. Carlson has measured the light absorption-coefficients of iodine and of tri-iodide ion (I_3^-) in aqueous solution. In the blue and violet the latter is found to absorb much more strongly than the former.

6. QUANTITATIVE SPECTROSCOPIC ANALYSIS

Mr. R. Hultgren, in collaboration with Professor R. M. Badger, has been working on the development of spectroscopic methods of chemical analysis with the purpose of making them more generally applicable and especially of increasing the precision of estimation in cases where a substance to be analyzed contains several elements. A systematic investigation is being conducted of the mutual effects of various elements on the intensities of their spectral lines emitted in the spark; and it has been found that under certain rather special conditions these mutual effects may be made very small.

7. Band Spectra and Symmetry Relations of Polyatomic Molecules

A program has been instituted by Professor R. M. Badger for the investigation of some of the simpler polyatomic gases by means of a study of their band spectra in the photographic infra-red. This is a region as yet very little studied, and offers the advantage that the spectra found here have a comparatively simple structure.

So far, ammonia, acetylene and ethylene have been studied and their absorption-spectra submitted to a practically complete analysis. Acetylene was found to be a linear molecule giving rise to very simple double bands, with alternate lines having an intensity ratio 3 to 1, resulting from the fact that the hydrogen nuclei have each a spin of one-half unit, while the carbon nuclei have no resultant spin. Ammonia and ethylene give rise to much more complicated spectra, from which some interesting information as to the dimensions and symmetry of these molecules has been deduced.

8 General Physics

Professor R. C. Tolman has continued his researches on the extension of thermodynamics to general relativity by the publication of treatments on the use of the energy-momentum principle in general relativity, on the use of the entropy principle in general relativity, and on the application of his system of relativistic thermodynamics to thermal equilibrium in a gravitational field. The latter work has shown the necessity for a minute temperature-gradient in a fluid which has come to thermodynamic and gravitational equilibrium, in order to prevent the flow of heat from places of higher to those of lower gravitational potential. Professor Tolman has also investigated the derivation of a non-static cosmological line element for the description of the large-scale phenomena of the universe, and applied it to the red-shift in the light from the nebulæ, the annihilation of matter in the universe, and the relation between the angular extensions and luminosities of the nebulæ.

Publications

During the past year thirty-two articles have been published describing the researches outlined above or in last year's Year Book.

Sherman, H. C., Columbia University, New York, New York. *Chemical investigation of the amylases and related enzymes.* (For previous reports see Year Books Nos. 11–28.)

During the year two papers recording results of our experimental research upon properties of malt amylase, as briefly noted in previous reports, have been published in the Journal of the American Chemical Society.

A paper dealing with the comprehensive and critical study of the purification of pancreatic amylase has been brought into final form for publication and will appear in an early issue of the Journal of Biological Chemistry.

The experimental work of the year has been a direct extension of the line of research in which the purification work just mentioned constituted the completion of an important step. Our success in formulating the improved method of purification made possible the preparation of this amylase at more uniformly optimal enzymic activity and in larger yields than had previously been possible; and this in turn has permitted us to advance still further the evidence of chemical individuality of this product.

Undoubtedly, the most widely accredited criterion of chemical homogeneity is the ordered spatial arrangement of a crystalline state and we are gratified to be able to report that a crystalline substance having amylase activity, only slightly less than the amylase activity of the preparation in solution from which the crystals were formed, has been obtained.

The accumulated knowledge of the properties of pancreatic amylase indicates quite conclusively that it is protein. Several methods have been successfully established by other workers for the crystallization of various proteins. The antecedent successes in the crystallization of other proteins together with the knowledge of the particular properties of pancreatic amylase have been the basis of the attempts to crystallize this enzyme. The crystalline material referred to was obtained from alcohol-water systems of the highly active purified amylase preparations buffered by means of phosphates. In the light of our experience up to the present time it appears that the following conditions should be carefully studied and observed if crystalline material is to be obtained. (1) The purified preparations should be freshly prepared. (2) The concentration of the purified preparation in solution must be just sufficient to allow a slow deposition of the solid phase as the temperature is gradually lowered. (3) The solutions of the purified material at the start should be prepared at low temperatures, seemingly not above 5° C., and the temperature gradually lowered; since at temperatures above 5° C. the protein material is denatured with consequent loss of solubility, and crystal formation does not take place. (4) The hydrogen-ion activity of the solution is adjusted by means of phosphate buffers in such concentration that they are not separated out at the temperatures employed. Both formation and yield of crystals are very dependent upon the hydrogen-ion activity of the system. (5) In a very limited number of experiments it appears that the presence of sodium chloride facilitates crystallization of the enzymic material.

The organic crystalline material already obtained consists of isotropic elongated crystals which exhibit slight double refraction. The index of refraction as determined by immersion is approximately 1.54. The microscopic form of the crystals was examined by Professor P. F. Kerr of the Department of Mineralogy of Columbia University to whom we gratefully acknowledge our indebtedness. In the dry state the crystalline material gives a positive color reaction with Millon's reagent, an additional indication of its protein nature. We hope to study further the chemical nature of the crystals.

The efficient collaboration of those who have shared in this work, whether as research assistants or as volunteers, is gratefully acknowledged.

GENETICS

Babcock, E. B., University of California Agricultural Experiment Station, Berkeley, California. *Investigations in the genus Crepis.* (For previous reports see Year Books Nos. 25–28.)

Development of all phases of these investigations has continued. Below are summarized the new results secured during the past year.

EVOLUTIONARY PROCESSES IN CREPIS

A review of evidence thus far accumulated on the taxonomy, genetics and cytology of *Crepis* has led to the following generalizations regarding the internal processes which have operated or are operating to bring about the origin and differentiation of species. Thus far about one-third of the known species have been studied in living condition. Comparison of the somatic chromosomes of these species, together with the evidence from external morphology and genetics gives some indication of the processes in question, which fall into three general categories, *viz,* genic mutation, chromosomal variation and interspecific hybridization.

Genic mutation—Evidence that alterations in individual genes is a general evolutionary process is found in the numerous polymorphous species, in some of which it is known that the great majority of plants possess the normal diploid number of chromosomes. Their individual character differences are inherited according to Mendelian principles and their more widely divergent races differ in several or many genes. The appearance of paleæ on the receptacle in hybrids between certain distinct races of *C. capillaris* is an instance of reversion due to union of genes from two races. Presence of paleæ is recessive to absence of paleæ in this species and, as presence of paleæ is probably older phylogenetically, a progressive step occurred in the evolution of *Crepis* through a dominant mutation conditioning naked receptacle. One such instance is more important than much negative evidence regarding the nature of point mutations in general. Another genic variation which may have played some part in the evolution of *Crepis* is the interspecific lethal found in *C. tectorum.* These last two are discontinuous variations and are therefore at variance with the idea that evolution proceeds continuously.

Chromosomal variation—That intraspecific alterations in chromosomes are important processes in the evolution of *Crepis* is indicated by three lines of evidence. From the study of phylogenetic relationship in 67 species, it was found that morphologically similar species have similar chromosomes. From comparison of closely related species it appears that corresponding chromosomes must have changed independently of one another. Increase and decrease in both number and size of the chromosomes must have occurred. From study of the numerical relations it is clear that intraspecific changes have affected individual pairs of chromosomes as well as whole n groups. Changes in individual pairs may come about through transformational processes—fragmentation, deletion, translocation, etc. Processes leading to polyploidy also play a certain rôle in the evolution of

Crepis. But in spite of the remarkable range of chromosome numbers in *Crepis*, chromosome morphology is of greater general significance in phylogeny and evolution. The transformational processes, since they could induce not only differences in chromosome morphology but also those changes in chromosome number which would account for the 6, 8, 10 portion of the series, must be considered the most basic of the processes connected with chromosomal variation.

Interspecific hybridization—Natural hybrids have been found among both Old World and New World species and it is probable that hybridization occurs frequently in regions occupied by different species. It does not necessarily follow, however, that interspecific hybridization is the most important evolutionary process in *Crepis*. Artificial hybrids have been secured from over a hundred different combinations of thirty-six species of *Crepis*, but only about one-fifth of these hybrids were sufficiently fertile to produce much seed even under natural conditions and these were practically all hybrids between very closely related species. The low fertility of interspecific hybrids does not prevent their utilization in genetic investigations. Thus far such investigations have brought to light only two methods by which this process might have been effective in the origin of more than a few rare or exceptional species in *Crepis*, *viz*, autosyndesis and amphidiploidy. Functioning of the former is necessarily limited to hybrids in which at least one of the parental species is polyploid. Consequently it has no bearing on a difficult phylogenetic problem, *viz*, origin of the 6, 8, 10, 12, 14, 22 series of diploid chromosome numbers. Amphidiploidy may have functioned in the origin of 12, 14, and 22, yet both of these processes fail to account for the 6, 8, 10 portion of the series. Since genic mutation can not account for this, we are compelled to resort to the little understood transformational processes as the most reasonable explanation.

CHROMOSOMAL VARIATIONS

Haploid Crepis capillaris—Dr. Hollingshead reports that five haploid plants of this species have been found in populations of *capillaris-tectorum* F_1 hybrids numbering over 3000 plants. They doubtless resulted from parthenogenetic development of *capillaris* egg cells. These haploids resembled reduced diploids but differed noticeably from diploids in leaf shape and habit of growth. Root tips usually showed the haploid chromosome complex of three individually different chromosomes, but parts of some root tips in each haploid were diploid and some root tips were wholly diploid. A few parts of most of the plants above ground were also diploid, giving rise to diploid and chimeral heads and branches. The haploid portions of the plants were sterile but achenes were obtained from diploid parts of one haploid plant. The progeny, presumably completely homozygous, were remarkably uniform in appearance.

In meiotic behavior (P. M. C's) the haploids were irregular and variable. They resembled other haploids previously described in the occurrence of a random segregation of the daughter halves to different poles, or "non-reduction." New or unusual features were (1) the occasional division of univalents at diaphase, (2) the frequent division of univalents but the inclusion of most pairs of daughter halves in the same nucleus, and (3) the omission of the homotypic division. As a result microspores of normal chromosome constitution were rarely formed and very little good pollen was produced.

In diploid tissue on a haploid plant three bivalents were formed in many P. M. C's, but non-conjunction of one or more chromosome pairs was a frequent occurrence. This lack of pairing between presumably completely homologous chromosomes is of great theoretical interest, for it shows that complete homology does not necessarily result in bivalent formation at meiosis.

An unbalanced somatic chromosomal variation in Crepis tectorum—Dr. M. Navashin reports that among many progeny of a triploid individual of this species one sectorial chromosomal chimera was found. There were three shoots of which one was normal diploid and two were triplo-B simple trisomic. The trisomic component did not differ in any way from complete trisomic plants of corresponding type. The diploid component was morphologically identical with ordinary diploid plants of the same species, but differed from them in that its fertility was greatly reduced. The origin of this chimera is explained as due to loss of the extra B chromosome early in development of a trisomic individual. The variation in chromosomal composition took place only once, thus establishing a lineage of cells of new chromosomal type. Frequent variation making it impossible for the cell progenies to possess uniform chromosomal constitution leads to variegation.

A case of "chromosomal variegation" in this species was also observed. Among several hundred seedlings derived from a normal diploid plant, one was found in which the meristematic cells of the root tip differed in various ways from one another in chromosomal constitution. The process of chromosomal variation seems to have occurred in either direction, *i.e.*, either addition or subtraction of certain chromosomes takes place. It is suggested that somatic chromosomal variation may lead under some circumstances to "bud variation" or even to true somatic segregation if one allelomorphic chromosome of a heterozygous individual is replaced by another. Genetic variegation may sometimes result from chromosomal variegation.

INTERSPECIFIC HYBRIDS

Crepis capillaris ($n = 3$) x *Crepis tectorum* ($n = 4$), *hybrids and hybrid derivatives*—Dr. Hollingshead has corroborated M. Navashin's observation of amphiplasty in this species hybrid. She found that the satellite of one *tectorum* chromosome is absent; and measurements of the various chromosomes indicated that in the reciprocal hybrids examined another *tectorum* chromosome was shorter than in the parental species. Meiotic irregularities in these F_1 hybrids were numerous, with considerable variation in the number of bivalents formed at diaphase. In hybrids involving one strain of *tectorum,* three bivalents and one univalent was the most frequent combination and seven univalents were very rare. In those involving a second strain of *tectorum* the frequencies of the various combinations of bivalents and univalents were approximately equal, with three bivalents and one univalent the least frequent combination. This suggests an explanation for apparently conflicting evidence reported in the case of other interspecific hybrids. The univalent chromosomes in the P. M. C. of these F_1 hybrids divided at the first or second meiotic division, but not at both. The hybrids were almost completely sterile.

Triplex hybrids containing 2*n*-*capillaris* and *n*-*tectorum* were found and selfed progenies were obtained from two of them. The *capillaris* chromosomes united to form three bivalents at meiosis, leaving the tectorum chromosomes unpaired. The chromosomes of the progeny indicated that only male gametes which had none or all of the *tectorum* chromosomes functioned, but that most or all of the female gametes could function. Thus plants were found with 2*n*-*capillaris* chromosomes and with 2*n*-*capillaris* plus various combinations of *tectorum* chromosomes. With the exception of the triplex hybrids (like the parents), plants with *tectorum* chromosomes were less viable than those without. This constitutes evidence against a theory which could account for an increase in chromosome number during the evolution of *Crepis* by the addition of a pair of chromosomes from another species following hybridization.

One amphidiploid derivative (with a diploid chromosome complex from each species) was secured. It was less vigorous than triplex hybrids of the same generation but matured earlier. Meiotic irregularities were very frequent and a large proportion of the pollen was bad. This plant was completely sterile. No explanation of the lack of vigor was found; but the meiotic irregularities may have been introduced from the *capillaris* parent which was of a strain which frequently exhibits meiotic irregularity. Under the circumstances it would be premature to infer that the lack of vigor and the meiotic irregularity of this plant is evidence against the hypothesis which would account for some of the chromosome numbers in *Crepis* by interspecific hybridization followed by amphidiploidy.

Crepis rubra ($n = 5$) x *Crepis fœtida* ($n = 5$) *and some derivatives*—Mr. C. F. Poole has studied a population of 28 plants derived from selfing the backcross progeny of F_1 x *C. fœtida rhœadifolia.* The character contrasts, purple vs. yellow anther tubes and nodding vs. erect flower heads before anthesis, the former of each pair from *rubra* and the latter from *fœtida rhœadifolia,* are definitely correlated with a chromosome pair, C_rC_f. This evidence necessitates revision of Navashin's scheme of homology for the five pairs of chromosomes in these two species. In the revised scheme Navashin's A_rA_f, B_rB_f and E_rE_f are retained; but his D_f becomes C_f and his C_f is homologized with D_r. Furthermore, by selfing the backcross progeny of F_1 x *rubra,* a sufficient range in chromosome distribution was obtained, so that upon the basis of random distribution of the two heteromorphic pairs C_rC_f and D_rD_f, a close agreement of observed with expected assortment was obtained.

An F_1 hybrid was obtained from *C. rubra* x *C. fœtida typica.* In the F_1 and some of the highly heterozygous derivatives meiotic figures were found to exhibit instances of conjugation of all five pairs of chromosomes. Nine F_2 plants were secured from the selfed F_1 and these were of three types, *viz,* diploid (3), triplex or sesquidiploid (5), and amphidiploid (1). On the basis of this evidence it is estimated that 61 per cent of the F_1 gametes were haploid and 39 per cent diploid. The amphidiploid derivative is the third case of amphidiploids to be reported in *Crepis* and, unlike the other two which were completely sterile, this plant was fairly self-fertile, producing 55 achenes on 22 heads. Although the two species, *rubra* and *fœtida,* are very distinct morphologically, yet there is sufficiently close relationship so that homologous chromosomes from the two species tend to form quadrivalents during meiosis and the resulting irregularities at reduction cause diminution of fertility. Positive evidence now exists, therefore, that amphidiploidy following interspecific hybridization can have functioned in the origin of new species of *Crepis.*

This report is based upon papers published or filed in the University of California Library during the year (see Bibliography under Babcock, Hollingshead, Navashin, Poole).

The following persons have assisted in the work during the past year: Mr. C. W. Haney, technical assistant; Dr. Lillian Hollingshead, Mr. C. F. Poole, Mr. D. R. Cameron, Mr. J. A. Jenkins, research assistants.

INDIAN ART

Blish, Helen H., University of Nebraska, Lincoln, Nebraska. *Study of the art of the Plains Indians, with particular relation to work on a pictographic Sioux manuscript.* (For previous report see Year Book No. 28.)

This study has been continued by means of a grant from the Carnegie Corporation of New York to the Carnegie Institution of Washington. Most of the academic year was spent in putting the page-by-page editing of the Bad Heart Buffalo (Bull) manuscript into final form and in going forward with the preparation of the introductory chapters in criticism of the Oglala artist's work—from the standpoints of both history and art. This involved much investigation of library sources and constant correspondence with my interpreter assistant, John Colhoff, who was in direct contact with the Indians themselves.

The article on Dakota ethics, prepared the previous year, was revised and is being published as one of the University Studies of the University of Nebraska.

The summer season of 1930 was given over to field work. Most of the time was spent on the Pine Ridge Reservation, South Dakota, as in the two previous years, securing material from the Indians, chiefly the two old men, He Dog and Short Buffalo, and the artist's sister Dollie. Several days were spent in the north central part of Wyoming in an attempt to locate certain historical pictographic cliff records of the early Dakotas, which might have considerable bearing on the present work. Effort has been and is being centered on the finishing of my own manuscript in exposition of the Indian record in order that it may be ready for as early a publication as can be arranged.

METEOROLOGY

Bjerknes, V., Oslo, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5–28.)

The method of weather analysis, which since the year 1918 has been developed in Bergen, Norway, thanks largely to the support of the Carnegie Institution of Washington, has been characterized very strikingly as an *indirect aerology;* conclusions concerning the conditions in the higher atmospheric strata are drawn indirectly from the observations made at the ground, without help of direct aerological observations from the higher strata. It has therefore always been highly desirable, to bring the results of the indirect aerology, and of the theoretical conclusions drawn from them, under the test of direct aerological observations. The opportunity for this has hitherto been very limited. The aerological observations which, since the beginning of this century, have been arranged internationally, have not been organized for this purpose. They have given confirmations only of a few general points.

The construction of the Jaumotte meteorograph, which is more accurate and at the same time much cheaper and much lighter than its predecessors, has now made it possible to organize aerological ascents suited to our purpose. This has led to a collaboration, mentioned already in previous reports of Dr. J. Bjerknes with director Jaumotte, Brussels. The result of the first successful group of ascents can now be given.

From the analysis of the weather charts a cold front with subsequent high-pressure wedge, which was followed by a new cyclone, was seen to approach Brussels from the west December 26, 1928. From 11 o'clock that day to 11 o'clock of the 28th, 31 meteorographs were sent up at regular intervals; 26 instruments were recovered, 18 of them having serviceable registering curves. Almost all of these had reached great heights in the stratosphere. These 18 records gave a very complete vertical section, going through the entire tongue of cold air and ending in the center of the following cyclone. This section has now been worked out fully by Dr. Bjerknes, and discussed in connection with the charts from the ground and other available observations from the same period.

Among the numerous interesting results the following shall be mentioned.

1. Combining the section thus obtained with some ascents available from other places it has proved possible to draw a topographic map of the surface bounding the tongue of cold air. This map in general confirms the conclusions drawn by the indirect aerology. In its northern highest part the cold air fills the whole of the troposphere (height 8000 to 9000 meters). Thus the outbreaks of cold polar air are large scale phenomena and not limited merely to the lower strata of the troposphere, as has been postulated by certain meteorologists.

2. The tropopause (*i.e.* the boundary surface between stratosphere and troposphere) showed great variations of height of a more or less regular wave character, with height differences of two kilometers or more from

troughs to crests. As the instruments were sent up from one place merely, it has not been possible to determine the true lengths and the velocities of propagation of these waves, but attention will be paid to this question by future ascents. Instruments will then be sent up from at least two stations.

3. These waves are connected with considerable pressure variations in the highest strata of the troposphere, but hardly any effect of these pressure variations could be observed at the ground. This contradicts a theory which has been subject to much discussion in late years, that relatively small pressure variations in high strata should produce great pressure differences at the ground, and thus be the cause of great disturbances below.

4. A discussion of the temperature distribution in these tropopause waves leads to the following capital fact: the orbital motion producing them is not vertical, as in small scale waves, *but nearly horizontal.* The slope of the tropopause towards the pole (about 1 to 800) causes even horizontal motions to produce waves and crests. The north-south component of this horizontal orbital motion brings light masses under the crests and heavy masses under the troughs. Thereby the pressure differences existing in the higher strata are balanced below.

5. That the orbital motion must be practically horizontal in waves having a period of the order of magnitude of a day has been predicted in papers previously referred to in these reports, as the phenomenon comes as a result of the earth's rotation (*cf.* V. Bjerknes, *Dynamics of the Circular Vortex,* Geofysiske Publikationer, Kristiania 1921; H. Solberg: *Integrationen der atmosphärischen Störungsgleichungen, ibid,* Oslo 1928). The verification of this prediction is very important, as this is a fundamental point in the wave theory of cyclones.

It is very encouraging that already the first group of ascents with the Jaumotte meteorograph has given so many valuable results. These investigations will therefore be continued to such an extent as available means will permit.

Besides this work of Dr. Bjerknes the main efforts of this year have been concentrated upon the preparation of a textbook of *Physical Hydrodynamics with Applications to Meteorology.*

All existing textbooks deal with fluids which are either incompressible, or which have a density depending merely upon the pressure. A fluid with such strongly idealized properties can not perform work in a thermodynamic engine, and can not be made to circulate by thermal effects. This gives the full explanation why "classical hydrodynamics" has exerted so little influence upon the sciences of atmosphere and hydrosphere. Our entire work on the application of hydrodynamics and thermodynamics to meteorology and hydrography has, from the theoretical point of view, been based upon theorems of that more general "physical hydrodynamics," in which the fluids have their actual physical properties and which contain the "classical hydrodynamics" as a special case.

As our work proceeds, the more it becomese evident that it would be useful to prepare a systematic textbook of physical hydrodynamics, including the most obvious applications especially to meteorology. This is now being done, the theoretical part being worked out by Prof. V. Bjerknes and H. Solberg, and the theoretical part by Dr. J. Bjerknes and H. Bergeron.

NUTRITION

Mendel, L. B., and H. B. Vickery, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3–28.)

Experience with thousands of rats has demonstrated that their growth can readily be modified through a wide range of rates of gain by suitable variations in the character as well as the quantity of their rations. Thus the animals can be made to "mark time," even in early adolescence, without change in body weight during a period far longer than that which usually intervenes until full adult size is reached. Growth may be resumed whenever the diet is suitably altered. Again, rats may be fed so as to gain at the rate of 2 grams of body weight daily during the period of most rapid increase in size. This has been the "average" accomplishment for the male albino rat under the usual laboratory conditions, and has furnished data for the preparation of the conventional graphs of so-called "normal" growth. The daily gains can, however, be made to approximate 5 grams, or even more, if suitable food mixtures are selected. These varied manifestations of growth can be secured in animals of the same strain reared under identical conditions in a common environment. Genetical explanations are therefore ruled out of consideration.

Normal growth has been defined as a correlated increment in the mass of the organism that occurs within a definite interval of time in a way that is characteristic for the species. It involves composition, form and the rate of gain. Perfect growth and development imply a far-reaching correlation of the various parts of the body. An upset in this nicely balanced relationship is speedily recognized as an anomaly. The energy content and the chemical nature of the food are insufficient to explain the consummation and maintenance of a normal, as contrasted with an abnormal, composition of the cells. The specificity of growth is marked; there is regularity and characteristic individuality of the ontogenetic development in each species. Abnormal growth may involve the correlation feature and likewise the time element.

There has been a tendency in the past to make mere gain in size an index of proper growth. As was pointed out in a previous report, however, it by no means follows that an animal, which has made very rapid gains as the result of appropriate feeding, represents a more ideal state of nutrition or physiological development than that of an individual which has grown at more nearly the "average" rate. This involves the question of what "optimal" growth really is. The ability to develop gains at widely different rates, in genetically related animals, affords an opportunity to make comparisons of them from various standpoints. At the present time Mr. Gairdner Moment, working in Professor Harrison's laboratory at Yale University, and Miss Julia Outhouse, in Professor Mendel's laboratory, are engaged in elaborate comparative measurements of various organs and tissues of rats from our inbred stock that we have raised to the same body weights at widely differing rates. In addition to the determination of the weights of the liver, spleen, kidneys, thyroid, pituitary, thymus, testes, ventricle of the heart, selected muscles, eyes, and parts of the skeleton, elaborate histological examinations are being made and some of the bones are being analyzed chemically. Among the tentative findings are indications that the very rapidly growing rats are essentially "normal" for their weight in respect to the relative weights of the organs examined. Under the conditions of the experiment, as conducted with the albino rat on a favorable regimen, it would seem that *rate* of growth has little influence on skeletal development, as judged by the dimensions of the long bones and of certain body systems, *i.e.*, pelvic girdle, thorax, dental apparatus and skull. In the *growing* animal body, proportions, stature or size are dependent, apparently, on body weight and have little, if any, relationship to the age of the individual; hence weight and size are here synonymous. No information has yet been obtained on the effect of maintenance of weight in either the adult or the young on the developmental aspects of the skeletal system. The high correlation between body size and bone size may be explained on the assumption that the size of the organic matrix, upon which the inorganic salts are deposited in the process of ossification, must be dependent on the general body size. Age undoubtedly is a factor in determining the degree of calcification. The data have not as yet been critically evaluated.

Differences that may have significance have been found in the young 60-gram animal. In the slow-growing individuals all the third molars have erupted, while those that attain this weight 10 to 15 days earlier have only their first and second molar teeth. From this it may be judged that eruption of teeth is an age factor and not one of rate of growth. It is doubtful whether any increase in the organs mentioned takes place after a total body weight of 420 grams has been reached. The observations also confirm the current belief that the number of individual fibers in a muscle is determined in very early life; subsequent "growth" involves primarily an enlargement of those fibers already present. The entire study will require considerable time for its completion.

The program for the study of the tissues produced during rapid growth has called for diets that would promote the developmental processes, considered in terms of gain in weight, as rapidly as possible. In the attempt to secure maximal rates of growth various rations were tested. The reasons for the selections of the ingredients need not be detailed here. Some of the food mixtures used, with the outcome of the tests measured in terms of days required for male rats to grow from 60 to 200 grams in weight, are given in the table on page 382.

The mixture of inorganic salts, often referred to as the Osborne-Mendel IV salts, that is widely used to supply the mineral nutrients in feeding experiments, represents a formula based primarily on the analysis of the ash of milk, with certain supplements of less common elements that occur in traces in natural foods. The Osborne-Mendel mixture is ordinarily prepared to include 0.0025 per cent of iodine, a quantity that was arbitrarily chosen. It has been reported that larger quantities of iodine produce beneficial results measured by the growth of rats to full adult size. On the assumption of an average daily food intake of 7 grams per rat for the *unsupplemented conventional food mixtures in which the customary proportions* of the Osborne-Mendel salt mixture are included, the daily iodine intake will be about 0.007 milligram. We have conducted new feeding and growth tests in which a daily further addition of 1.107 milligrams of potassium iodide was included in the food intake over long periods of time. This corresponds to about 0.23 gram (3½ grains) daily for an adult person of 70 kilograms and might represent the daily amount used during a course of mild medication with iodide. There was no apparent superiority for the diets thus supplemented; insofar as growth and physical appearance of the animals indicate, prolonged administration of small doses of iodide is apparently harmless. We have also conducted comparable tests of several salt mixtures currently employed in other laboratories for the preparation of so-called "synthetic" diets. All ingredients of the rations other than the mineral nutrients were identical. No outstanding advantages were observed, so that there seems to be no warrant at present for altering the Osborne-Mendel prescription.

Ration	*Per cent*	Rat number	Days required	Average
Whole wheat	27	B8137	40	44 days = 3.2 gm. gain per day
Rolled oats	26	B8173	47	
Yellow corn	25	B8150	39	
Oil meal	15	B8221	44	
Casein	5	B8121	49	
Cod liver oil	1	B8160	42	
NaCl	0.5			
$CaCO_3$	0.5			
+ whole milk				
Meat residue	23	B8363	29	32 days = 4.4 gm. gain per day
Rolled oats	71	B8360	29	
IV salts	4	B8357	34	
Cod liver oil	2	B8367	30	
		B8356	31	
		B8353	37	
Casein	35	B8402	28	30 days = 4.7 gm. gain per day
IV salts	4	B8361	26	
Starch	37	B8362	31	
Butter fat	9	B8369	27	
Lard	15	B8354	36	
+ 0.4 gm. liver and 20 gm. lettuce daily				

The collaboration with Dr. Francis G. Benedict of the Nutrition Laboratory in the study of the respiratory metabolism of the rat is being continued with the assistance of Miss Kathryn Horst in Professor Mendel's laboratory in Yale University. The results will be reported in detail by Dr. Benedict. The influence of the rate of growth, senescence, unduly large weight, and exercise, on the basal metabolic rate have been investigated in detail. Special activity cages have been devised for part of this undertaking. Studies of body composition in terms of nitrogen, fat and water have formed part of the program of ascertaining the fundamental metabolic phenomena of a widely investigated species.

The employment of the albino rat in a large variety of physiological investigations has given prominence to the problem of the successful breeding of these animals. Failure to secure young rats of suitable size has been experienced in many laboratories in which stock colonies are maintained. Recognizing the urgent need for better information on various aspects of the reproductive cycle, we have encouraged Prof. Arthur H. Smith and Mr. W. E. Anderson of the Department of Physiological Chemistry in Yale University to use the facilities of our laboratory to throw further light upon the questions at issue. The records that we have collected of more than twenty thousand rats should be helpful in this connection. The new investigations are planned to extend over a relatively long period. At present the influence of the duration of the period of rest between pregnancies is under consideration.

The elaborate program undertaken in collaboration with Prof. E. A. Park of the Johns Hopkins Medical School, for the study of the development of the bones in rats, particularly with reference to the deposition of the inorganic constituents and the histological changes involved, has been referred to in several previous reports. During the past year parallel feeding experiments have been conducted in New Haven and Baltimore with identical food materials prepared in a single laboratory. The tests were conducted at approximately the same season of the year, and the animals were placed on the selected dietary regimens at the same age and for the same periods of feeding. This has made it possible to ascertain whether environmental factors and differences in stock are likely to modify, in any noteworthy way, the outcome of tests with inadequate diets. The new comparisons have involved the use of food mixtures as follows:

	per cent
Edestin	22
Starch	62
Lard	10
Salt mixture XXX[1]	3.2

and supplements as mentioned below.

This mixture (without further additions) is free from calcium and phosphorus. The latter elements were added in varied proportions so that any desired ratio of calcium to phosphorus could be secured. Vitamins B and G were supplied in the form of yeast in which suitable inclusions of calcium salts were made to produce the same calcium-phosphorus ratio as in the basal organic food mixture. Refined maize oil, with or without inclusion of irradiated ergosterol, was also given in daily doses. Thus the effect of the different ratios of calcium to phosphorus could be observed in the presence or absence of vitamin D in the food. Similar comparisons of the influence of varying ratios of calcium to phosphorus superimposed on the so-called Steenbock rickets-producing diet have also been instituted. In some of the series the content of calcium has been kept constant in all the food mixtures, and variations in the additions of phosphorus provided the changes in ratio; in others the phosphorus content was kept unvaried throughout and the calcium was varied. The experiments thus afforded observations of the effects of food in which the outstanding differences were in the proportions of the bone-forming mineral elements, as follows:

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[1] This mixture is devoid of calcium and phosphorus. See Year Book 1926-1927, p. 355, for composition.

Calcium : Phosphorus = 1:1; 1:0.7; 1:0.5; 1:0.3 (calcium constant)
" " 0.7:1; 0.5:1; 0.3:1 (phosphorus constant)

The gross autopsy examinations, analyses of blood and selected bones, as well as detailed histological examinations are being completed at present.

The reproductive and accessory reproductive tissues from many of the above mentioned animals are being examined histologically by Dr. Karl E. Mason of Vanderbilt University in connection with his studies on the ability of the anti-sterility factor, vitamin E, to prevent testicular degeneration in the presence of a deficiency in one of the other vitamin factors. Our new food formula described in detail in the report for 1926–27 provides a vitamin D deficient diet closely comparable to that used by Dr. Mason in his studies on the male genital system following deficiency of vitamins A and B. Dr. Mason reports that testicular changes occur in these vitamin D deficient rats and that several times the minimal dosage of vitamin E is incapable of exerting any protective effect. This is in accord with similar results obtained by Dr. Mason in studies on the relation between vitamins A and E, but contrary to the findings in regard to the effectiveness of vitamin E therapy in B deficiency. This indicates, as Dr. Mason believes, some close interrelationship of the fat-soluble vitamins A, D and E in the normal functional activity of the male reproductive system.

As a supplement to the findings regarding the dietary properties of water cress (*Nasturtium officinale*) in last year's report we have now demonstrated an abundance of vitamin E in the green leaves of this plant. Male and female rats were grown from the period soon after weaning to full sexual maturity on diets in which water cress formed the sole source of the "fertility factor." These animals were intermated repeatedly and numerous litters were thus secured. Furthermore, the testes of forty male rats, kept on a ration in which water cress offered the only possibility of securing vitamin E, were examined histologically by Dr. Mason. He reported that, with a single unexplained exception, all of the animals exhibited normal testes. In each case slides were prepared from both the testis and epididymis. This makes the diagnosis more trustworthy because often the testis will appear quite normal while the epididymis may show many sloughed cells and reduction in the number of mature spermatozoa, thus indicating that the germinal epithelium of the testis is not as near to the normal as histological examination might indicate. Abnormalities were not found in either organ. Dr. Mason adds that his findings indicate a high vitamin E content in water cress. He believes, on the basis of our quantitative data, that the dried water cress may be at least two or three times as rich in the E factor as is the equivalent amount of dried lettuce.

Chemical examination has failed to demonstrate the presence of the poisonous alkaloid nicotine in the seeds of the tobacco plant which is now under detailed study in our laboratory. It seemed desirable to check the presumed lack of toxicity of these seeds by tests on animals. The seed used has the following proximate composition: [1]

	per cent
Water	3.34
Ash	3.71
Protein (N x 5.34)	20 76
Fiber	14.44
Carbohydrate (other than fiber):	
Water-soluble after hydrolysis, calculated as dextrose	3.08
Cell wall constituents, pentoses, etc., calculated as dextrose, acid hydrolysis	0.55
Alkaline hydrolysis	0.00
Undetermined	11.89
Fat, ether extract	42.23

Rats eat this seed greedily. A number of animals have already grown at an average normal rate for more than 109 days on a mixture that contains tobacco seed 99 per cent, calcium carbonate 0.5 per cent and sodium chloride 0.5 per cent. There is thus reason to believe that tobacco seed contains proteins of good "biological quality," and that it includes at least vitamins A, B and G in reasonable abundance. No advantage seems thus far to accrue from additions of a more complex salt mixture to the unusual ration already mentioned. The further study of the nutritive factors in the tobacco seed is being prosecuted vigorously.

Our studies of the chemical properties of the amino acids that result from the complete hydrolysis of proteins have been continued throughout the year. We mentioned, in our last report, that cystine had been found to form an insoluble compound with silver at faintly acid reactions. The investigation of this compound has led to some surprisingly significant results. The substance that precipitates, when a solution of cystine in sulphuric acid is treated with an excess of silver sulphate and neutralized to pH 6, is not a compound of cystine at all but is, in fact, a silver mercaptide of cysteine of the formula $(C_3H_5NSO_2Ag)_2.Ag_2SO_4$. An extensive reduction occurs under these conditions and from 70 to 85 per cent of the nitrogen of the cystine taken can be recovered from the cysteine mercaptide as cystine. The balance of the nitrogen is found in the filtrate, for the most part apparently in the form of oxidation products of cystine. Of these, two only have been identified, ammonia and cysteic acid, both in small proportion. The reduction reaction that occurs is, so far as we can tell, simple and results only in the formation of cysteine. The oxidation reactions are, however, complex and give rise to a mixture.

The simultaneous formation of cysteine and of cysteic acid from cystine, under the action of so mild a reagent as silver sulphate in faintly acid solution, is not without biochemical significance. We may suppose that some, at least, of the cystine undergoes a reaction that may be expressed

$$3\ R\text{-}S\text{-}S\text{-}R + 3\ H_2O \longrightarrow R\text{-}SO_3H + 5\ R\text{-}SH$$

This reaction bears certain analogies to the well-known Canizzaro reaction, but in this case a disulphide plays the part of the aldehyde and is simultaneously oxidized to a sulphonic acid and reduced to a thio-alcohol or mercaptan. In view of the high order of the above reaction it is improbable that so simple a course is pursued. The equation as written serves merely to keep in mind the relationship of the final products to the starting point. However this may be, the production of cysteic acid from cystine provides a mechanism whereby the formation of taurine in the animal body may be explained. Decarboxylation of cysteic acid leads to this substance and the possible genetic relationship of taurine to cystine is evident.

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[1] We are indebted to the Analytical Department of the Connecticut Agricultural Experiment Station for the analysis of this seed. The protein factor is based on the nitrogen content of the isolated crystalline globulin.

A silver compound different from the above is formed when an alkaline solution of cystine is treated with an excess of silver nitrate. This substance was described many years ago by Neuberg and Mayer as the normal silver salt of cystine. Our attempts to prepare it, however, indicated that the normal silver salt undergoes spontaneous transformation to the silver mercaptide of cysteine and homogeneous products could not be secured. Since the publication of the above results, an analogous behavior of cystine with mercuric sulphate has been reported by Andrews.

The behavior of cystine and cysteine with silver sulphate in acid solution accounts for the failure of our attempts last year, in collaboration with Doctors Eagles and Vars, to secure more than a suggestion that a thiol-imidazole compound may be present among the products of hydrolysis of zein. As we mentioned at that time the "compound appears to be so unstable under the conditions that we have employed that its isolation will have to await the development of more suitable methods." It now seems probable that the substance derived from zein, which responds to Hunter's thiol-imidazole test, combined with silver to form a mercaptide and that this derivative subsequently decomposed in such a way that its identity was lost.

The analytical investigations of proteins have been continued. We referred last year to the material aid rendered by the observation that cystine can be separated from histidine by taking advantage of the great insolubility of the copper salt of cystine. It is now clear that cystine is a probable impurity in histidine fractions derived from proteins by the silver precipitation method and we now employ the treatment with copper hydroxide as a routine procedure for its removal. Our interest in cystine led us to investigate the basic amino acid composition of human hair, a tissue which yields an unusually high proportion of this amino acid. We were concerned with the investigation of modifications of the silver precipitation method which are required when dealing with a solution that contains high proportions of cystine and low proportions of histidine. This was an extension of our policy of applying this method to proteins that yield uncommon distributions of the amino acids. Human hair yielded 0.5 per cent of histidine, 8.0 per cent of arginine, and 2.5 per cent of lysine. The indirect colorimetric method indicated that it likewise yielded 16.5 per cent of cystine.

Although it has long been known that tissues of this type are characterized by unusually high proportions of cystine it now became clear that the unusually low yield of histidine and moderately large yield of arginine were almost equally striking. With the view, therefore, of obtaining a better chemical definition of keratoid tissues, Mr. R. J. Block of the Department of Physiological Chemistry in Yale University, at our suggestion, conducted an analysis of wool. This tissue yielded 0.66 per cent of histidine, 7.8 per cent of arginine and 2.3 per cent of lysine, results that are in extraordinarily close agreement with those on human hair. The investigation of this type of tissue is therefore being continued.

The study of the constituents of plant cells, in progress for some years, has been actively continued with the able cooperation of Dr. G. W. Pucher of the Connecticut Agricultural Experiment Station staff, who is attached to our laboratory. For reasons that have been discussed in previous reports, we are devoting our attention to the tobacco plant.

It was noted, during a preliminary study of the seed of tobacco, that nicotine, while entirely absent from the unsprouted seed, was present in conspicuous amounts in the sprouts that develop in about 12 days when the seeds are scattered on blotting paper moistened with distilled water. It is evident, therefore, that this alkaloid is synthesized very early in the life of the plant and, with the object of ascertaining as much as possible regarding the chemistry of nicotine synthesis, we have spent considerable time upon a study of the tobacco seed. The proximate analysis given above indicates that the seed contains a high proportion of fat and a very low proportion of carbohydrate. It is thus a more or less typical oil-seed, like soy bean or many of the oily nuts. A considerable part of the protein of the seed can be extracted by treating the fat-free meal with 5 per cent sodium chloride solution. This extract, when diluted, deposits a protein of the globulin type in a beautifully crystalline form, provided the hydrogen ion activity is adjusted within the limits pH 5.8 to 6.2. The protein can also be prepared by salting out with ammonium sulphate or by dialysis according to the classical methods long employed by Osborne. A study of the chemical properties of this protein is now being conducted.

A hot-water extract of the fat-free meal has been prepared with the object of investigating the nature of the water-soluble substances of the seed. It may be presumed that much of this material is derived from the embryo and the extract therefore represents, as it were, the chemical environment in which growth begins. The investigation of this extract has already shown the presence of choline, betaine, adenine, guanine and arginine. It is hoped that a fairly comprehensive picture of its quantitative composition may be secured.

For the investigation of the composition of the leaf we have prepared extracts from 50 kilogram lots of fresh mature leaf and from similar quantities of fresh leaf that have been allowed to reach each of the four well-recognized stages in the curing process as applied to tobacco. Analyses of the proximate composition of this material have also been made. The detailed examination will require considerable time but some results have already been secured. The plan of investigation falls into two natural divisions. First, the study of the different forms of nitrogen together with the isolation of as large a part of the nitrogen as possible in the form of chemically pure substances. Second, a study of the carbohydrates and organic acids of the leaf with the view to the investigation of the metabolism of nitrogen-free substances. For the isolation of the organic acids we have depended upon the precipitation of the barium salts in the presence of alcohol, a method that we first applied to alfalfa some years ago and in which we are now placing an increasing degree of confidence. The acids are actually isolated as their ethyl esters by means of fractional distillation *in vacuo* in an efficient fractionating column. In this way fumaric, succinic, malic and citric acids have already been isolated and evidence obtained of the presence of additional allied substances. We have also secured evidence of the presence of acidic substances of a type different from these, as well as of ether soluble components that have some of the properties of complex phenols.

The investigation of methods of proximate analysis for nitrogenous constituents of tobacco have been continued. Published papers that describe methods to determine ammonia and amide nitrogen and also nitrate nitrogen were mentioned last year.

It was found that the determination of the total nitrogen by the salicylic acid-zinc method in an aqueous solution of plant material that contains nitrates may be seriously in error owing to the loss of much of the nitrate nitrogen. This confirmed the published observations of Ranker. In order to avoid this error we have developed a method that may be applied to such extracts without resort to the lengthy and troublesome drying operations Ranker advocated. The method depends upon a preliminary reduction of the nitrates by the action of dilute sulphuric acid on reduced iron powder. An ordinary Kjeldahl digestion is then carried out on the solution. The method was shown to be accurate by the analysis of solutions of known composition.

We have found the apparent dissociation constants of nicotine to be $pK'a_1 = 3.22$ and $pK'a_2 = 8.11$ at 20°. These values are in close agreement with previous determinations of Kolthoff but the method we employed was more precise than his and the data are more comprehensive. The constants have been employed in the development of a simple method to determine the so-called "free nicotine" of tobacco, which is a part of the routine examination of commercial tobacco in analytical laboratories. Incidental to this investigation, we found an easy method for the preparation of nicotine of high purity, and also isolated pure nicotimine, a little-known volatile alkaloid that accompanies nicotine in tobacco.

We stated in last year's report that "the determination of the amide nitrogen of tobacco-leaf extracts is simple, once an accurate method for ammonia nitrogen has been found." Data obtained since have given us reason to modify this assertion. It was found that widely variable results were obtained if the hydrolysis of the amide preliminary to the distillation of the ammonia so formed was carried out with 1 N or with 5 N hydrochloric acid and the time of hydrolysis was lengthened from 4 hours to 20 hours. Nearly three times as much apparent amide nitrogen was indicated when the more severe conditions of hydrolysis were applied. A search for the explanation of this striking result showed that once again the high nitrate content of certain tobacco extracts had interfered with the application of a classical indirect method of analysis. This, however, was only part of the difficulty; at least two mechanisms enter into the reaction. In the first place the mixture of hydrochloric acid with the nitric acid present in the extract sets up a strongly oxidizing condition and, granted the presence of substances that are readily oxidized, a part of the nitric acid ultimately is converted to ammonia. The high results obtained for ammonia when fresh leaf extracts were hydrolyzed with relatively strong hydrochloric acid for a long time were thus accounted for. But when extracts from partially cured tobacco leaf were treated in the same way there was very little increase in total apparent amide nitrogen, and in extracts from fully cured tobacco there was actually less apparent amide nitrogen, when the results of hydrolysis under the extreme conditions were compared with results under mild conditions. This curious observation compelled us to assume that there is present in fresh leaf an easily oxidized substance that behaves as third member in the system with hydrochloric and nitric acid and gives rise to the production of ammonia. Furthermore we were driven to suppose that this easily oxidizable substance is nearly completely destroyed when fresh tobacco leaf is partially cured. The losses in apparent amide nitrogen under extreme conditions of hydrolysis, as compared with mild conditions, that were observed when dealing with more fully cured tobacco could be accounted for by actual oxidation of ammonia by the mixture of hydrochloric and nitric acids. A similar reaction was observed when a few milligrams of ammonia were treated with mixed acids under conditions approximating those employed in the amide nitrogen determinations.

A method was devised whereby the true amide nitrogen content of these various extracts could be determined since the substitution of sulphuric acid for hydrochloric acid gave identical results when widely different concentrations of acid and times of hydrolysis were employed. No evidence of the nature of the third member of the system was, however, secured. We could simulate the behavior of fresh tobacco leaf extracts, with respect to the reduction of nitric acid to ammonia, by adding a little capryl alcohol to a mixture of hydrochloric and nitric acid and boiling for some time. This, however, merely shows that the phenomenon has something to do with an easily oxidized substance and gives no information of the identity of the third member of the system in the fresh leaf. This experience is another example of the extreme care that must be taken in the interpretation of data secured by indirect methods on plant material. A paper describing this work is in preparation.

It is perhaps fitting to record in this place that the Connecticut Agricultural Experiment Station has recently published a bulletin as a memorial to the late Dr. Thomas B. Osborne, for many years a research associate of the Carnegie Institution and in charge of this laboratory. In it are reprinted a number of his papers that have general interest, together with various tributes from his associates and friends and a complete bibliography of his work.

Williams, R. R., and Walter H. Eddy, Teachers College, Columbia University, New York, N. Y. *Physiological functions of vitamins.* (For previous reports see Year Books Nos. 27 and 28.)

The following report is submitted as a result of studies continued with support of funds authorized by the Carnegie Corporation of New York to the Carnegie Institution of Washington for a four-year period beginning April 1927.

Further characterization of the B group of vitamins has constituted the major field of effort during the past year as in previous years.

At the time of our last report, we were about to complete a large scale fractionation of rice polish in an attempt to repeat the work of Jansen and Donath.[1] We rounded out this study by testing on both rats and pigeons a small quantity of the supposedly pure crystalline vitamin B_1 kindly supplied by Dr. B. C. P. Jansen to one of us on the occasion of a very interesting visit to his laboratory in Amsterdam.

As the foregoing work has been published in some detail[2] we need only summarize the findings here: (*a*) We did not succeed in isolating the crystalline substance, $C_6H_{10}N_2O$, but did obtain obviously impure products which closely approximated it in physiological properties, both qualitatively and quantitatively; (*b*) the scattering of activity in discard fractions was more extensive than we anticipated from Jansen and Donath's account;[1] (*c*) there was evidence of qualitative decline of physiological properties during the fractionation suggesting the gradual elimination of substances of physiological importance other than the antineuritic vitamin, B_1; (*d*) lastly and most important of all, we found that our most refined products as well as Dr. Jansen's crystals had the property of stimulating growth of rats on a B_1-free diet, but did not increase the weights of pigeons on a polished rice diet, though preventing the onset of polyneuritis in both species.

This latter effect we regard as the final necessary evidence that vitamin B, as hitherto recognized by either rat or pigeon feeding experiments, consists of a number of chemical entities besides B_1 and B_2. Each of these must ultimately be laboriously characterized and isolated. There is no one substance, or even two, capable of producing the manifold physiological effects formerly attributed to vitamin B.

During the past year Peters[3] reported tests which further substantiated our claims for the existence of a pigeon weight-maintaining factor separate from B_1 or B_2 as first suggested by Williams and Waterman[4] in 1928. We have devoted further efforts to the characterization of this B_3 factor during the past year.[5] This work included a survey of a considerable variety of foodstuffs in the hope of finding a superior source of this vitamin. Di Mattei[6] ascribed to sunflower seed the merit of so supplementing the diet of pigeons on polished rice as to prevent weight loss in spite of the regular appearance of pure symptoms of polyneuritis. Di Mattei's findings have been emphatically disputed by other experimenters[7] but the suggestion that sunflower seed might be particularly rich in what we called B_3 seemed worth investigation. After many trials of the material under a variety of conditions, we have taken an intermediate position in the dispute. It appears that sunflower seed contains B_3 rather abundantly as evidenced by its tendency to reduce weight loss of pigeons on polished rice. But it is by no means free of antineuritic properties as Di Mattei reported, though relatively much poorer in this respect than either yeast or rice polish.

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[1] B. C. P. Jansen and W. F. Donath, Mededeel Dienst Volksgezondheit Nederland-Indie, pt. 1, 186, 1926.

[2] R. R. Williams, R. E. Waterman and S. Gurin, Jour. Biol. Chem., vol. 87, 559, 1930.

[3] R. A. Peters, Harben Lectures, Jour. State Med., vol. 38, 28, 1930. London.

[4] R. R. Williams and R. E. Waterman, Jour. Biol. Chem., vol. 78, 311, 1928.

[5] W. H. Eddy, S. Gurin and J. C. Keresztesy, Jour. Biol. Chem., vol. 87, 729, 1930.

[6] P. Di Mattei, Arch. Fisiol., vol. 25, 56, 1927.
R. Reitano and G. Sanfillipo, Boll. Soc. ital. biol. sper., vol. 4, 510, 1929.

[7] E. Schmitz and E. George, Biochem. Zeit., vol. 204, 165, 1929.

With sunflower seed as a source material, we are endeavoring to elaborate a scheme for approximate isolation of this vitamin. So far our success has been meager, partly because of the difficulty in finding a diet fully adequate for pigeons in every other respect. Polished rice is obviously deficient in several particulars, probably in salts, proteins and fat-soluble vitamins as well as at least two B vitamins. However, extension of our work to chicks as well as pigeons, and the comparisons of foodstuffs as sources of this factor and experiments on thermolability[5] further strengthen our belief in the existence of a B_3 quite distinct in properties and function from B_1 or B_2. We have been unable to show the need for this factor in rat nutrition, but find it a potent force in the weight maintenance of both pigeons and chicks.

In our 1928 report we tentatively referred to evidence that a third B factor is needed for rats, and for convenience referred to the hypothetical substance as B_4. In 1929 Reader[8] working in Peters' laboratory at Oxford definitely postulated a third B factor essential to rat nutrition. To this factor she assigned the name B_3. During the past year she has further characterized this rat factor,[9] and at the meeting of the English Biochemical Society in June 1930 reported progress in its concentration and isolation. It was the privilege of one of us to attend this meeting and to discuss with the English workers the evidence and experiments. We have recently received from Dr. Harriet Chick, chairman of the English nomenclature committee, a statement that the confusion over the rival claims to B_3 has been resolved by them by assigning to Williams and Waterman the term B_3 for the pigeon factor and to Miss Reader the term B_4 for designation of her new rat factor.

Miss Reader's B_4 factor represents a recognition of the inadequacy of a combination of a classic B_2 source with B_1 for normal rat growth. Originally[8] she derived evidence of B_4 existence by showing that yeast autoclaved at pH 9 for one hour at 120° C. retained one physiological factor (B_2) but lost another (B_4). By examination of the fractions obtained by Kinnersley and Peters[10] in their preparation of a B_1 concentrate, she found first that the final concentrate was free of B_4. Searching for it among the discards she found it in the mercuric sulfate precipitate. From this precipitate she has since obtained a concentrate of B_4. With this material she has shown that while B_1 plus B_4, or B_1 plus B_2, are inadequate to normal growth of the rat and that increasing dosage of these factors fails to provide that normal growth, the addition of the B_4 concentrate to B_1 as provided by Peters' concentrate and B_2 as furnished by pH 9 autoclaved yeast results in such normality.

Reader's use of yeast extract autoclaved at pH 9 led Chick and Roscoe[11] at first to question Reader's use of this source of B_2 as evidence in favor of her new factor. Citing the work of our laboratory[12] as bearing on this point and extending their own studies on the thermolability of B_2 they find with us that B_2 is far from thermostable under alkaline conditions. They show that 4 to 5 hours autoclaving of yeast extract held at a pH of 8.3 to 10 and at a temperature of 122° to 125° may result in 75 to 100 per cent destruction of B_2. In this particular paper[11] they seriously questioned whether Reader's results might have been due to reduction of the quantity of B_2 in the autoclaved pH 9 marmite rather than to destruction of a new factor. Reader's further work with the concentrate obtained from the mercuric sulfate fraction and collateral evidence seems, however, to have clarified the situation and justified her B_4 claims. The explanation is apparently that both B_2 and B_4 are somewhat thermolabile, the latter much more so. This interpretation is in full accord with our earlier observations and was in fact in our minds as a probability at the time our paper on thermolability was written, as is indicated by a careful special definition of B_2 in that paper as well as by reference in our 1928 report in the Year Book to evidence suggesting possibility of a B_4 factor.

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[8] V. Reader, Biochem. Jour., vol. 23, 689, 1929.

[9] V. Reader, Biochem. Jour., vol. 24, 77, 1930.

[10] Kinnersley and R. A. Peters, Biochem. Jour., vol.21, 777, 1927.

[11] H. Chick and M. Roscoe, Biochem. Jour., vol. 24, 105, 1930.

The development of Reader's claims has again emphasized serious defect in our present definition of B_2 and the need for further study of this factor. Reader proposed that B_2 be defined as the dermatitis preventing substance. Chick and Roscoe[11] say:

> "It would be more satisfactory if in the assay of vitamin B_2 the criterion could be the prevention or cure of the dermatitis (rat pellagra?) developed in rats deprived of this vitamin, rather than the maintenance of growth. The irregularity in the time of onset of symptoms and in the degree of their severity would, however, make such symptoms untrustworthy and quantitative results impossible."

B_2 or G in a vague sense has widely received the alternate title of anti-pellagric vitamin and been assumed identical with Goldberger's P–P, especially in this country. Materials are claimed to contain this vitamin if they supplement rat growth when added to a basal diet free of B vitamin and supplemented otherwise with B_1. Anti-pellagric potency of foodstuffs on the basis of such growth-test results has been assumed without collateral evidence of their power to prevent or cure pellagra. In spite of the difficulties which we agree exist, we commend Miss Reader's attempt at a closer definition of B_2.

We have used in tests aimed to develop the functions of other B factors, such as B_1 and B_4 beef extracts, egg white and autoclaved yeast preparations on the assumption that they are rich sources of B_2 and free of other factors in the B group. We have confined our studies largely to those factors in which we have had primary concern, *viz*, B_1 and B_3. Defects of our animal test methods have, however, forced us to give attention to the characterization of B_2. This led to our work on the autoclaving of yeast[12] and has recently made us study more carefully the effect of methods of purification

[12] R. R. Williams, R. E. Waterman and S. Gurin, Jour. Biol. Chem., vol. 83, 321, 1929.

of the ingredients of the basal diets upon their significance in vitamin assay. We have also during the past few months had the cooperation of Dr. James Denton who was at one time associated with Dr. Goldberger in attempting to distinguish histologically between dermatitis symptoms in rats and true pellagra.

We have in preparation a paper[13] by Gurin, Denton and Ammerman which will present evidence that rat dermatitic symptoms vary histologically, sometimes resembling human pellagra in showing fundamental changes in the basal layer of the skin and sometimes lacking such changes. The so-called fundamental changes develop in rats on diets containing abundance of substances credited with pellagra-preventing properties, *viz*, egg white, beef extract and neutral autoclaved yeast and such symptoms are prevented or promptly cured by acid autoclaved yeast. This paper also reviews experimentally methods of extraction of casein, the relative effect of such caseins and of various sources of vitamin B_1 and B_2 on skin condition and growth of rats. As the details are about to be published, we need not describe them more fully here. These studies have, however, led us to doubt whether skin lesions in rats constitute evidence of true pellagra, as the dietary and histological findings are apparently in direct conflict. We certainly are not prepared to accept growth stimulation by beef extract and autoclaved yeast as evidence of anti-pellagric potency.

The resolution of these confusions in definition of B_2 and its sources is essential to both the proper characterization of B_2 and the development of feeding tests to establish the physiological limitations of other B factors. The use of some other animal than rats or birds might contribute materially to this result. It would be of interest to know what response dogs would make to diets such as produce pellagra-like symptoms in rats.

In the study of B_1 our greatest need was a large supply of pure B_1. To that end we have begun a ton-scale fractionation of rice polish. With the experience gained in previous fractionations by the Jansen and Donath method and by the introduction of several devices that promise to improve their procedure we hope to obtain a reasonable supply of a pure crystalline product.

We feel that the past year has produced marked progress toward the resolution of the confusion about the vitamin B complex arising from uncertainty as to the numbers of factors involved and the indefinite symptomatology associated with the deficiency of each. Personal contact with Dr. Jansen and the English workers in the field during the year has helped materially in eliminating elements of doubt about reported data and in permitting the formulation of new experiments.

VITAMIN C STUDIES

In our 1929 report we referred to studies[14] aimed to resolve the relation of vitamin C to dentition of the guinea-pig and to utilize these facts in the formulation of a method of assay for this vitamin. Through the further studies of Dalldorf and Zall[15] in our laboratories, marked progress in this direction has resulted. They have shown that guinea-pig tooth regeneration

[13] S. Gurin, J. Denton and M. Ammerman, In preparation.

[14] W. H. Eddy, Am. Jour. Public Health, vol. 19, 1309, 1930.

[15] G. Dalldorf and C. Zall, Jour. Exper. Med., vol. 52, 57, 1930.

is definitely correlated with vitamin C dosage, and this relation has suggested a simpler method of vitamin C assay than that suggested by Höjer[16].

These studies have, however, assumed a wider aspect as related to the whole subject of dental nutrition. They have added contribution to the views of Drain and Boyd, Howe and Wolbach, the Mellanbys and Hanke that resistance to caries, periodontoclasia, gingivitis, etc., may bear a much closer relation to diet and its effect on tooth structure than has hitherto been suspected. Our studies in the rôle of vitamin C in dentition have therefore been extended and a progrom of cooperative effort with the Columbia University School of Dentistry organized for the coming year.

BIOS STUDIES

While work on vitamin B and C has constituted our main endeavor in the year past, we have cooperated with Roger Williams in his bios studies by supplying fractions and discards from our Jansen-Donath fractionations for his bios tests. A result has been his publication[17] that while the Jansen crystals provide a greater stimulatory effect on O. P. yeast growth than the "Z" preparations previously developed by him, certain of our discards in this series showed even greater potency. These results seem to still further support Fulmer's original contention that Wildier's bios is multiple in character, that the stimulation of the growth of any given yeast strain is the sum of the effect of a group of factors rather than that bios is a single entity.

Criticism of our alpha and beta bioses as not entitled to such name has been expressed by Narayanan[18] during the past year on the basis that growth stimulation by them is of markedly lower magnitude than that of a number of other concentrates, including one separated by this investigator. He also finds no support for Miller and Lucas' contention that bios is a complex requiring the presence of two substances to produce physiological effect or that Eascott's inositol is one of these pieces of bios.

Roger Williams' work has emphasized the fact that different strains of yeast differ widely and qualitatively in response to growth stimulants. It is also evident that there are a number of substances capable of stimulating yeast growth in an artificial medium. Some of these substances are effective in very minute concentration and produce large stimulation of growth in low concentration. Others produce no effect in low concentration and only relatively small stimulation of growth in any concentration. These facts suggest that yeast metabolism involves a group of factors perhaps as varied and distinct in effect as those involved in animal nutrition. It may well be that our alpha and beta substances correspond more closely in function to the amino acids essential to animal nutrition than they do to the vitamins required by animals. This is less probable in the case of substances of high potency such as Narayanan's, R. J. Williams' and Jansen and Donath's preparations. We doubt, however, whether any single substance should be designated as "bios" until it can be clearly shown that the substance so designated substantially accounts for the phenomenon originally observed by Wildiers.

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[16] A. Höjer, Brit. Jour. Expl. Path., vol. 7, 356, 1926.

[17] Roger Williams, Jour Biol. Chem., vol. 87, 1930.

[18] B. T. Narayanan, Biochem. Jour., vol. 24, 6, 1930.

Our original interest in bios was due to its possible relation to the vitamin B. If the bios effect is not due to a single or limited series of factors there seems little hope that study of the factors concerned in yeast growth can contribute much to vitamin physiology. We have therefore limited our studies in this field during the present year to such fractions as we had already isolated and those, such as the Jansen and Donath fractions, that still suggest possible relation between vitamin B and the bios effect.

We have been fortunate in the assistance of a staff of workers, upon whom has fallen a large part of the responsibility not only of doing the experiments but also of planning them and interpreting the results. We express our warm sense of indebtedness to Messrs. R. E. Waterman, Samuel Gurin and John C. Keresteszy and to Misses Marion Ammerman and Minerva Kellogg for such constructive help.

PALEONTOLOGY

Merriam, John C., and Associates. *Continuation of paleontological researches.* (For previous reports see Year Books Nos. 20–28.)

The group of investigators who have been undertaking comprehensive studies in history of life in the Pacific Coast region with financial assistance from the Institution have carried forward their work during the past year with as close adherence as possible to the original program. As usual extensive field studies have been carried on by members of this group, and important papers resulting from such investigations are in process of publication.

The studies of Mr. Merriam have involved examination of nearly all of the problems upon which investigations of this group have touched and also the study of a wide range of geological and paleontological questions expressed in the scientific research program of National Park Service. Special attention has been given to study of those questions which relate to beginnings of life as conducted under the guidance of Dr. David White and the beginnings of human history as carried out by M. R. Harrington in cooperation with Dr. Chester Stock. Careful study has been given to a wide range of geological research problems, the development of which will represent some of the next important steps in furtherance of education and research in the great National Parks. A portion of the problem for study has concerned itself with possibilities for bringing out the most fundamental principles of geological and paleontological history in such manner as to make them intelligible to the visiting public.

The following reports have been submitted relating to the work of Dr. Buwalda, Dr. Kellogg and Dr. Stock, and a report from Dr. Chaney appears in the report of the Division of Plant Biology in the present volume.

Investigations by John P. Buwalda

Progress in the investigations centering on the Tertiary history of the John Day region of central Oregon consisted during the year 1929–30 mainly in advancing toward publication the results of the field work of previous years.

Field researches were confined to three areas during the year, all of which are highly diagnostic regarding the Tertiary history and structural development of a much larger surrounding region.

The mapping of the Indio Hills, an area of Tertiary formations lying near the northwest end of the long trough the southern part of which is occupied by the Gulf of California, and which also contains Imperial Valley, was nearly completed in collaboration with W. Layton Stanton. A short preliminary paper regarding the results of this work was published in Science during the year. The nature of the formations, their relations, and their structure reveal an intensely interesting chapter in the history of deposition, erosion, climatic changes, and the tectonic development of the Salton Basin. This trough, depressed below sea-level, is apparently an expression of that profound zone of crustal disturbance known as the San Andreas fault and its branches. It has usually been thought that the Salton

Basin was occupied by the sea until a recent date in its geological history, and that the sea was excluded by the construction of a dam across the trough in the form of the Colorado River delta, but our researches seem to indicate that the sea has not occupied the present topographic trough. Its earlier incursion, in Tertiary times, occurred before the present landscape came into being, and enormous topographic changes have occurred since the invasion. Apparently the sinking of the bottom of the trough below sea-level occurred recently and after the delta had been built to sufficient dimensions to exclude the sea continuously from the subsiding area.

Another critical area in California geology is the Tejon Pass district, in which the Sierra Nevada and Coast Ranges join. A real mapping by the writer and by members of the California Institute Summer Field Course led to the discovery of certain unique mountain structures. One of these, involving Fraser Mountain west of Tejon Pass, has been investigated further in collaboration with C. Lewis Gazin and J. Clark Sutherland. The mountain is an immense slab of granitic rocks of great age lying upon relatively young, upper Tertiary sediments, a relationship which could have been developed only through overthrusting in an acute way. The exact mechanics are not yet fully understood but the structure is astounding in character and is receiving further study. A preliminary announcement regarding the structure and Tertiary history of the area was made in a paper before the Cordilleran Section of the Geological Society of America at the 1930 meeting.

The San Andreas fault, one of the most remarkable of the Earth's structural features, suffered a maximum horizontal displacement of about 21 feet during the 1906 earthquake in the San Francisco region. It became a matter of interest whether the movement of the west side northward is habitual for this fault, and whether such shifts have occurred along it repeatedly in the past, aggregating large total displacements. In collaboration with Mr. Harry O. Wood another section of the fault in Carrizo Plains, about 250 miles south of San Francisco, was studied to determine the nature and direction of the movement there. In this area the physiographic conditions are unusually favorable. As reported in a preliminary paper before the Cordilleran Section of the Geological Society the displacement of the western block is also northward in this area, as in the San Francisco region, and the minimum aggregate horizontal shift indicated by offset streams is approximately one mile.

Report of Researches of Remington Kellogg

In October 1929, as a result of a cooperative arrangement between the Carnegie Institution of Washington and the United States National Museum, Remington Kellogg and Norman H. Boss were engaged in field work in the zeuglodont beds of Alabama and Mississippi. Search for additional remains of these Upper Eocene zeuglodonts was mainly confined to exposures of the Jackson formation in Washington and Choctaw Counties, Alabama, and in Clarke County, Mississippi. The discovery of an exceptionally well-preserved skull and both lower jaws and parts of the skeleton of five individuals of the little zeuglodont *Zygorhiza minor* will add to our knowledge of the Upper Eocene history of this group. An effort was made to interview old residents in the region visited for information in regard to the collecting localities of Dr. Albert Koch. Dr. Koch visited Alabama in 1845 and collected portions of skeletons of several individuals of *Basilosaurus cetoides*. These remains were procured chiefly in the vicinity of Clarksville in Clarke County, and near Old Washington Court House in Washington County, Alabama. Parts of several individuals were combined to form a composite skeleton some 114 feet in length. This skeleton was exhibited by Koch as a Sea Serpent, *Hydrarchus sillimani*, on Broadway in New York City. It was afterwards exhibited in the principal cities of Europe, and ultimately purchased for the "Königl. Anatomischen Museum" in Berlin. Again in 1848, Dr. Koch returned to Alabama and collected a fairly complete skull of *Basilosaurus cetoides* near Cullomburg in Choctaw County. This skull was later acquired by the Chicago Academy of Sciences and was destroyed at the time of the Chicago fire. The exact location of the zeuglodont remains collected by Charles Schuchert in 1894 and 1896 was ascertained from individuals who assisted Schuchert in the work of excavation and shipment of his collection.

At the invitation of the Economic Committee of The League of Nations, Remington Kellogg attended a conference on matters pertaining to the conservation of whales at Berlin, April 3 to 5, 1930. A draft convention was drawn up by those participating in this conference and this has since been submitted by the League to the several nations whose nationals are at present engaged in commercial whaling. Following this conference, through the generosity of the Carnegie Institution of Washington, the necessary arrangements were made for a tour of European museums for the purpose of studying fossil marine mammals. Notes were made on fossil marine mammals in the following institutions: Geologisch-Paläontologisches Institut und Museum der Universität at Berlin; Paläontologisch Sammlung, Alte Akademie at Munich; Württembergische Naturaliensammlung at Stuttgart; Geologisch-Palaontologischen Abteilung des Naturhistorischen Museums at Vienna; Istituto di Museo Geologico, Regia Universita degli Studi at Padua; Museo Geologico Capellini, Regia Universita degli Studi at Bologna; Museo di Geologia, Palazzo Carignano, at Turin; Laboratoire de Paleontologie, Museum National d'Histoire Naturelle, at Paris; Musee Royal d'Histoire Naturelle de Belgique at Brussels; Teyler's Museum at Haarlem; and the British Museum of Natural History at London. The cordial cooperation and unrestricted facilities placed at my disposal by the responsible authorities of these institutions was most gratifying. The examination of these collections has materially advanced the project for "A study of the evolutionary history of the cetaceans" and has made possible comparative studies of fossil marine mammals from formations in North America with those from Europe and northern Africa.

In the course of the past year material from Tertiary formations in California has been placed at my disposal for study and description, and important additional discoveries have been made in the Calvert Miocene formation of Maryland.

The following paper is being prepared for press:

Pelagic Mammals from the Temblor formation of the Kern River Region, California. For: Proc. Calif. Acad. Sci., MS., 200 pp., illus.

Report of Researches by Chester Stock

Paleontological field investigations in the northern Great Basin Province were conducted during the summer of 1929 in cooperation with the California Institute of Technology. The collecting and field studies were carried on by E. L. Furlong, C. Lewis Gazin, F. D. Bode, S. W. Lohman and E. R. Inglee.

Additional collections of Tertiary mammalian remains were obtained in the middle John Day beds at the entrance to and in Haystack Valley, John Day Basin.

A careful study was made of all Mascall and Rattlesnake exposures north of the John Day River and east of the Mascall Ranch, near Dayville, Oregon. From the Mascall deposits were secured the remains of two carnivores (*Amphicyon* cf. *sinapius* Matthew and *Leptarctus oregonensis* Stock) new to the Mascall fauna. These forms have been recently described (Carnegie Inst. Wash. Pub. No. 404, Art. 4). The types are important as additions to the mammalian assemblage from this middle Miocene horizon, serving to establish more definitely the time relationships of the Mascall to middle Tertiary horizons known from areas lying beyond the John Day Basin. As a result of further field study of the Rattlesnake Pliocene, beaver remains (*Dipoides*) have been found, thus furnishing evidence of the presence of a type heretofore unrecorded in the Rattlesnake fauna.

The middle Miocene fauna known from the Skulls Springs locality in Malheur County, Oregon, was considerably enlarged by further collecting. This fauna has been studied in detail by Mr. Gazin and a complete report for publication is in progress.

Mr. E. L. Furlong has investigated the characters and relationships of the Pliocene antilocaprid genus *Sphenophalos*, basing his studies on materials collected in the Thousand Creek beds, Northwest Nevada, in Rattlesnake deposits of north-central Oregon, and in Pliocene formations exposed near Harper and Rome in Malheur County, Oregon. A comprehensive report describing new materials and discussing the relationships of *Sphenophalos* is in process of completion by Mr. Furlong.

Many illustrations for papers describing paleontological materials have been prepared by Mr. John L. Ridgway. Mr. Ridgway is completing a series of illustrations for an important contribution to the Pleistocene avifauna from Rancho La Brea by Dr. Hildegarde Howard.

The following papers have been published:

Stock, Chester: Oreodonts from the Sespe Deposits of South Mountain, Ventura County, California.

Stock, Chester: Carnivora New to the Mascall Miocene Fauna of Eastern Oregon.

Furlong, Eustace L.: *Capromeryx minor* Taylor from the McKittrick Pleistocene, California.

Gazin, C. Lewis: A Tertiary Vertebrate Fauna from the Upper Cuyama Drainage Basin, California.

Maxson, John H.: A Tertiary Mammalian Fauna from the Mint Canyon Formation of Southern California.

White, David, National Academy of Sciences, Washington, D. C. *Study of the fossil floras in the Grand Canyon, Arizona.* (For previous reports see Year Books Nos. 26–28.)

Field investigations of the very ancient floras were mainly confined to the examination of pre-Cambrian formations in the Grand Canyon and in northern Montana. Besides collecting additional material from the Bass limestone and the beds of passage to the Hakatai shale, a more thorough examination was made of the latter with reference to its conditions of deposition and the discovery of life remains of any kind. The Hakatai shale, which is heavily charged with iron and is largely a hematite red, consists for the most part of very fine silts, some of which are extremely fine-grained and argillaceous, though others verge into sands, some of which are relatively coarse. Traces represented by impressions or molds of minute, vermiform, twisted algæ are abundant in some of the finer-grained silts, even when they are slightly ripple-marked, due to the comparatively shallow depth of water. Remains of trails, more probably of algal than animal origin, also were found.

Many of the beds of Hakatai shale bear evidence of temporary exposure by reduction of the water body, and at several horizons impressions of salt crystals are relatively distinct, though with the replenishment of the water the cracks were generally more or less completely closed and the salts taken into solution in every observed case.

The Bass limestone, near the base of the Grand Canyon (Proterozoic) series, is a relatively thin formation in the vicinity of the Kaibab trail. It shows considerable variation in the character of the deposits of organic origin, especially in the upper part of the formation, where red hematitic shales are intercalated. To a surprising extent the different forms of lime deposits laid down by algæ vary from level to level. Lime-secreting algæ producing scales very much like those deposited by some of the modern "corallines" were very abundant at several horizons, especially in the beds transitional from the Bass to the Hakatai. On the other hand, the ferruginous material irregularly intercalated in the Bass limestone and sometimes forming small lenses or occupying irregular spaces between the heads of the low alga reefs reveals non-calcareous algæ similar to those abundant in the Hakatai. Some of these non-lime secreting algæ are believed to have played a rôle in the segregation of the iron, though it is probable that more of the work of iron deposition was accomplished by the higher bacteria than by the plants just mentioned, which are visible under a strong hand lens.

The silty shales forming the grayish zone in the upper part of the Hakatai reveal great numbers of very thin dark blotches which, so far as their constitution, including a weak carbonaceous residue, is visible, suggest dense micro-plankton aggregates. Whether this interpretation is correct remains to be seen. The collection made from this horizon has not yet been received, it having apparently been lost in transit.

A thin limestone bed lying near the top of the Bass limestone was found to contain great numbers of alga-formed scale deposits of relatively large size. Large numbers of fragments of sandy shale and balls of calcareous mud are found to have been irregularly incrusted by such scale deposits.

The environment was evidently one of clear water with moderate currents which caused the occasional rolling over of the incrusted fragments and the inwashing of grains of coarse sand which, with the incrustations, are now enveloped in the limestone stratum. The weathered surface of the rock reveals them as striking as well as significant exhibits. The limestone stratum, which lies between shales, is undeformed.

The success met in the search for evidence of life in the Unkar group made it very highly probable that the overlying Chuar group, of nearly equal thickness—namely, about 6000 feet—and described by Walcott as embracing great thicknesses of thin limestone and calcareous shales, would reveal as good or better plant remains, and that, further, in view of its later age and the generally more favorable nature of the deposits, remains of animals might be discovered. Plans to visit the Chuar in the Nankoweap and adjacent valleys on the eastern side of the Park in 1929 failed on account primarily of the lateness of arrival of Mr. White at Grand Canyon. However, in view of the importance of the question, plans were formulated somewhat carefully in the early spring of 1930 and, with the cordial cooperation of the National Park Service, arrangements were made for the organization and equipment of a pack train to enter that portion of the Canyon in May, while conditions as to climate and water as well as the availability of mules were favorable. It being impossible for Mr. White to visit the Canyon at that time, provision was made for putting the expedition in the charge of Dr. C. E. Resser, of the U. S. National Museum, a specialist in the study of the earliest Paleozoic invertebrates, and one who had had experience with Dr. C. D. Walcott in the collection of Cambrian and pre-Cambrian plant remains in Montana and British Columbia. With him was cooperatively associated Dr. A. A. Stoyanow, paleontologist of the University of Arizona, also a specialist in Paleozoic invertebrates. About 10 days were spent by the party in the northern basins of the Chuar, where thorough search was made for fossils.

Algal impressions and calcareous deposits of plant origin, including two or three new types, were found to be comparatively abundant in the Chuar, but no clearly recognizable traces of animal life were found. In view of the character of the deposits which, it would appear, should certainly yield evidence of animal life had it been present, it is difficult to avoid the conclusion either that the entire Grand Canyon series embracing the Unkar and Chuar groups, though abundantly populated by algæ of low orders, is of earlier age than has been supposed, so that it antedates the appearance of animal life of such organization as to have left recognizable traces, or that the environment, which may have been generally shallow and perhaps unstable fresh water, was not inhabited by animals having hard parts of such characters as to be discerned in the light of our present knowledge. The abundance of the plant life makes it appear highly probable that some kinds of animal life were present, though the organisms may have been so small and so soft or so unlike any known in the Paleozoic that their traces if visible are not yet recognized as of animal origin. The collections gathered from the Chuar group have not yet been examined. Some of the best material has been incorporated in the exhibits at Yavapai station.

Advantage was taken of the availability of Dr. Resser and Dr. Stoyanow for the furtherance of paleontological exploration and of the knowledge of the history of the Cambrian of the Grand Canyon section, and the determination of its relations to the Cambrian outcrops in other parts of Arizona. Accordingly, a fortnight was spent in the study of the Cambrian sections, including the remarkable exposures on the Kaibab trail, and the collection of fossils. Trilobites and other invertebrates were found at several localities. The most important discovery was that of middle Cambrian fossils in the Muav limestone, thus proving the Muav of earlier age than had been supposed.

The collections made by the expedition will in due time be deposited in the U. S. National Museum.

Meanwhile a collection embracing some very interesting specimens, one or two of which may represent types of alga deposit not known before, collected by Lincoln Ellsworth from the Bass limestone and deposited by him in the American Museum of Natural History, have been transmitted by the Museum with the request that they be included along with the material collected under Carnegie auspices in the detailed examination of the subject of Unkar plant life.

With the approval of the President of the Carnegie Institution a brief study was made in July 1929 of the Belt series (Proterozoic) as they are exposed in Glacier National Park, near the Canadian boundary in Montana. Four days only were spent in this Park. Considerable thicknesses of the Altyn limestone, the lowest formation of the Belt series in this region, were found to be made up of reefs formed by an algal growth comparable to though very much more elongated than the *Collenia* of the Grand Canyon section. Similar growth has been reported from the Mescal limestone in central Arizona, one of the pre-Cambrian limestones in the Great Slave Lake region of western Canada, and from the pre-Cambrian at several points in China. Learning that the form in the Altyn limestone had been observed and collected the previous year by Mrs. Mildred Adams Fenton of the University of Buffalo, further study of this fossil has been postponed.

At a higher horizon in the Altyn limestone there were found great numbers of blotch-like patches of dark carbonaceous matter in the ash-gray limestone matrix. These blotches, which are irregular in form and in some cases torn or fractured as though possessing a degree of brittleness, embrace large numbers, including two or more types of soft algæ comparable to those found in the Hakatai of the Grand Canyon section. As with the latter, these patches are tentatively interpreted as fragments of thin crust-like plankton. The material appears to have been somewhat spongy in constitution, but the carbonaceous residue, though readily determinable, is very thin and frail.

Higher formations of the Belt series were found to contain reefs and other alga-built calcareous deposits of varying forms. There was, however, no opportunity to make an extensive search or to collect adequate material. Evidently the Belt series, even its lowest and oldest members, contain abundant evidence of plant life, belonging, as would naturally be expected, to primitive types representing low orders of algæ.

Search of the base of the Supai, in the Grand Canyon, with the object of finding material better preserved for publication and description than that found previously was made at a number of points in the vicinity of Grand Canyon station, but without success. Plant fragments are present in small numbers at numerous localities, but invariably, so far as observed, they had either been subjected to destructive abrasion or were very seriously macerated.

The report describing the Permian plant life of the Hermit formation was issued under the title, *Flora of the Hermit shale, Grand Canyon, Arizona,* in December 1929, as Publication No. 405 of the Carnegie Institution.

PHYSICS

Clark University, Worcester, Massachusetts. *Expenses relating to rocket investigations undertaken by R. H. Goddard.*

Assistance granted by the Carnegie Institution for experimental studies of Dr. Goddard concerning exploration of the upper atmosphere by means of rockets, in association with support which this project has received in recent years from the Smithsonian Institution, has helped to direct attention to the fundamental character of such studies in relation to the development of physical science.

Dr. Goddard has projected a program involving the broader requirements for his work, and the interest in his studies has led to a large donation from the late Daniel Guggenheim, with the result that Dr. Goddard has been permitted to continue his experimental studies in rocket development and propulsion. The following advisory committee has been named to cooperate with Dr. Goddard in this program: Charles G. Abbot, Secretary of the Smithsonian Institution; Walter S. Adams, Director of the Mount Wilson Observatory; John A. Fleming, Acting Director of the Department of Terrestrial Magnetism; Charles F. Marvin, Chief of the U. S. Weather Bureau; John C. Merriam, President of Carnegie Institution of Washington; R. A. Millikan, of the California Institute of Technology; Colonel Henry Breckinridge; and Colonel Charles A. Lindbergh.

Compton, K. T., Princeton University, Princeton, New Jersey. *Investigations in the field of spectroscopy, conducted at Princeton University.* (For previous report see Year Book No. 28.)

Funds have been provided by the Carnegie Corporation of New York to the Carnegie Institution of Washington in support of this project.

The work in this field may be divided into three parts which correspond to the three objectives.

STUDIES IN GAS OPACITY

The chief object of these studies has been to investigate the physical processes which are involved in the formation of the Fraunhofer lines of the sun and analogous lines in other stellar spectra. The practical purpose of this study is to permit the gaining of information regarding the physical conditions existing in the reversing layer of the sun. The work which has been done in Princeton by Professor John Q. Stewart and Mr. Serge Korff has resulted in the publication of two scientific papers since the last report.

The first of these is entitled *Dispersion and Absorption Line Width in Alkali Vapors*, by Serge Korff (Physical Review, vol. 34, p. 457, 1929). In this work white light was passed through the vapors of sodium and of rubidium contained in a quartz furnace which could be heated to various temperatures to vary the vapor density of the absorbing alkali vapor. The emergent light was studied by a specially designed spectroscope. Analyzer measurements were made of the refractive index in the neighborhood of the absorption lines and also of the line width of the absorption lines. This work yielded a very precise verification of the classical equation for optical dispersion since this equation was verified within less than one per cent throughout. It was not possible to test the existence of negative terms which are introduced into the dispersion formula by the quantum theory since the theoretical magnitude of these terms for lines which could be studied was too small to be detected experimentally. Stewart's equation for the relation between refractive index and line width was verified.

The second paper is on *Distinction between Scattering and Absorption*, by John Q. Stewart and Serge Korff (Astro-Physical Journal, vol. 71, p. 62, 1930). In this work an apparatus was designed to simulate the conditions on the sun by providing a source of white light within the surrounding atmosphere of absorbing sodium vapor so that the emergent light exhibited absorption lines. The apparatus was enclosed in a container which could, when desired, be flooded externally with white light of the same quality as that which was introduced within the vapor. If then the absorption lines are due only to scattering of light, they should disappear when the vapor is flooded externally, as well as internally, with white light. If, however, true absorption of energy occurs, then the absorption line should still continue to appear dark when the external flood lights are used. The experiment showed that the outer edges of the absorption lines are attributable, primarily, to scattering, but that the center of the absorption line shows true absorption. This is a verification of a theory of Stewart and leads to a discussion of possible physical processes to account for the true absorption near the center of the line.

Assistance in this work was made through the services of an instrument maker whose salary was paid from the grant.

ANALYSIS OF SPECTRA

The analysis of the spectra of various elements has been carried on under the direction of Professor A. G. Shenstone and Professor H. N. Russell, with the assistance of Dr. H. A. Blair, Dr. J. J. Livingood, and Dr. J. H. Findley. This work has resulted in the publication of the following papers:

The Spark Spectrum of Cobalt: II, by J. H. Findley (Physical Review, vol. 36, p. 5, 1930).

The Spark Spectrum of Rhodium, by A. G. Shenstone and J. J. Livingood (Bulletin American Physical Society, vol. 5, No. 4, June 1930).

The Arc-Spectrum of Nickle, by Henry Norris Russell (Physical Review, vol. 34, p. 6, 1929).

The Arc-Spectrum of Palladium, by A. G. Shenstone (in course of publication).

The Spark Spectra of Silver and Gallium, Ag. II and Pd. II, An Extension, by H. A. Blair (Physical Review, vol. 36, 1930).

Arc-Spectrum of Copper, by A. G. Shenstone and H. A. Blair (in course of publication).

The Spark Spectrum of Copper, Cu. II, by A. G. Shenstone and H. A. Blair (still in progress).

A Method for Magnetic Analysis of the Spectrum by Means of Unresolved Zeeman Patterns and its Application to Silver, II, by A. G. Shenstone and H. A. Blair (Philosophical Magazine, vol. 8, Nov., 1929).

The above analyses have to do with a series of rather similarly related spectra in which the interest has been three-fold. First, to obtain the analysis of the spectra; second, to investigate certain departures from the standard laws of intensity and interval which are exhibited in spectra of this type; and third, to search for higher series numbers which are strangely difficult to excite in spectra of these elements.

Assistance in this work has been made by purchase of photographic supplies, minor spectroscopic equipment, the services of a computer whose salary has been paid from the grant, and the use of a calculating machine without which this work would have been extremely laborious.

SPECTROSCOPY OF THE EXTREME ULTRA-VIOLET

As described in the report of last year this investigation has involved, first, the consideration of the large vacuum spectrograph designed to give high dispersion and, at the same time, to permit simultaneous photographing of the entire spectrum from the shortest wave-lengths, up to the region of about 2200 Angstroms. This work has been done by Professor K. T Compton and Dr. J. C. Boyce, with the assistance of the mechanic who has been engaged with funds available from the grant. During the course of the year this spectrograph has been constructed and mounted, together with the necessary evacuating system and apparatus for purifying and circulating gases whose spectra are to be investigated. The final adjustments have been made and the results have been extremely encouraging. The first trial spectrum of oxygen shows sharp lines in the entire region from about 200 to 2300 Angstroms. A fluorite diaphragm operated magnetically in front of the slit can be used as a filter to cut out all lines below about 1300 and this has proved to be quite useful in separating first-order lines from high-order lines in the region above 1300. A special design of diaphragm in front of the plate holder operates to give a continuous variation in intensity of the line on the photographic plate from its maximum near the center to zero near an edge, by which means it is possible to investigate fine structure of lines which are strongly overexposed near the center and to obtain from a single photograph information which otherwise would require a series of photographs. As far as the spectroscopic adjustments are concerned, this spectrograph is now ready for serious operation.

Difficulty has been encountered in maintaining sufficiently good vacuum on account of leaks which develop with continued operation and which appear to be due to strains induced at the open end of the spectrograph when the end plate is screwed on to compress the rubber gaskets. Under favorable conditions a vacuum of 10^{-5} mm. has been obtained, but upon reopening the spectrograph and then reevacuating it has not been possible to reproduce this. At the present time, a change is being made in the open end of the spectrograph, whereby additional braces are provided to withstand these strains and, at the same time, a more advantageous arrangement of the rubber gaskets is being introduced further to reduce the strain. If this treatment is successful, it should be possible to proceed immediately with the spectroscopic use of the instrument.

In preparation for the work on ultra-violet spectroscopy, Dr. J. C. Boyce and Miss Janet MacInnes have compiled a complete list of wave-lengths of spectral lines which have been reported shorter than 2500 Angstroms and belonging to the elements whose spectra may occur in gas discharges. This list contains about 2000 lines classified according to wave-length in vacuum, wave-length in air, wave number, intensity, spectroscopic notation and reference to author. There has been no previous compilation, which is adequate, of wave-lengths in this region so that it is believed that this list will prove to be of considerable value to progress in the field of ultra-violet spectroscopy. This list has been mimeographed and bound in flexible cover and copies of it have been presented to a number of men who have been recently working in the field of ultra-violet spectroscopy. A number of additional copies are kept on hand for distribution to any who may request them and a notice of the availability of this list has been published in the Physical Review, Science, Nature, and Die Naturwissenschaften.

Committee on the Study of the Surface Features of the Moon. *Progress report for the period July 1929 to June 1930.* (For previous reports see Year Books Nos. 26 to 28.)

In the attempt to ascertain the kinds of materials that are exposed at the surface of the moon, the Committee has approached the problem from several different viewpoints and has devised methods and instruments suitable for the attack. The following three distinct lines of evidence indicate that the lunar surface materials are, for the most part, of the nature of pumice and volcanic ashes.

(1) The small amount of polarization in the light reflected by the moon proves that the materials are light colored, like pumice, granite or sandstone, and not dark, like basalt or other heavy rocks. The changes in the amount of polarization in the reflected light for different angles between incident and reflected rays prove that the lunar surface is rough and not smooth.

(2) The rapid chilling of the moon's surface during an eclipse proves that the surface materials are excellent heat insulators. This fact precludes large areas of massive rocks, such as granite, which, when heated to the boiling temperature of water (the temperature of the moon's surface at noon) and then set in a cool place, require a long time to cool down.

(3) In case the lunar surface materials resemble terrestrial rocks and are composed chiefly of silicates, they should show in the infra-red spectral region of wave lengths, 8 to 10μ, the low emissivity characteristic of silicates: This they fail to do. The observed heat effects are best explained on the assumption of unit emissivity for the moon's surface. This assumption does not, however, preclude the existence of pumice or other silicate rocks providing the lunar surface is very rough. The distribution of planetary heat over the moon's surface agrees with that from a rough surface composed of pumice or volcanic ashes.

The second and third lines of evidence are furnished by work recently published of Doctors Pettit and Nicholson on lunar radiation and temperatures. The radiation which reaches us from the moon consists of two parts: (*a*) reflected sunlight which is practically confined to the limits of wave length 0.3 to 8μ; and (*b*) the low temperature radiation called "planetary heat" which is emitted by the warmed surface and reaches us principally through the water-transmission band in the atmosphere between 8 and 14μ. The small amount of planetary heat transmitted through the atmosphere between 0.3 and 8μ is practically negligible.

With the aid of a vacuum thermoelement and screens of fluorite, glass, and a water cell mounted on a large reflecting telescope Doctors Pettit and Nicholson measured the relative amounts of spectral energy that come to us from different parts of the moon's surface. From the data thus obtained they computed the corresponding temperatures and found that at full moon when the subsolar point (sun directly overhead) is nearly central on the disk, its temperature is 134° C. or 273° F.; but that at quarter phase, when it is on the limb, the temperature is 85° C. or 185° F. The directive effect of the rough lunar surface on the planetary heat probably accounts for this difference. From the distribution curve of planetary heat about the subsolar point, the mean spherical rate of emission was found to be 1.93 cal cm^{-1} min^{-1} and the corresponding temperature 118° C. or 244° F. which is to be compared with the computed black-body temperature of 101° C. or 214° F. This discrepancy between the observed and theoretical rate of lunar emission is accounted for by slight inaccuracies in the determinations of the atmospheric absorption constants. The temperature on the dark side of the moon was found to be −153° C. or −244° F., a temperature so low that many additional observations will be needed to establish an accurate value. The temperature of the layer only 1 cm. below the surface is, even at noon, approximately that of freezing water or 0° C. and does not vary much during a complete lunation.

If silica and the silicates, which have high reflecting power in the spectral region 8 to 10μ, are present on the moon's surface, it might be supposed that the solar radiation reflected by the lunar surface would be great enough to affect the temperatures calculated on the assumption that all the radiation in these wave lengths is planetary heat radiated by the warmed surface of the moon. Calculations show, however, that the reflected radiation would be less than 1.5 per cent of the planetary heat, even if the reflection at the lunar surface were perfect over the whole atmospheric water-transmission band 8 to 14μ. This would decrease the computed temperatures about 1° C., which is less than the uncertainty arising from other sources. It is not easy, therefore, to prove by this means whether the lunar surface materials are silicate rocks. The emissivity of silicates is abnormally low between 8 and 10μ, and some indication of its presence should be revealed by the transmission of a fluorite screen which is opaque beyond 12μ and which isolates the spectral region 8 to 10μ. A comparison of the ratio of the observed planetary heat transmitted by the fluorite screen to that without a screen with the ratio computed by assuming (*a*) unit emissivity and (*b*) the emissivity of silica, yields for assumption (*a*) the ratio 0.37 to 0.38 and for assumption (*b*) 0.37 to 0.30. The second value is so different from the first, that for practical purposes the emissivity of the lunar surface may be considered to be unity for the spectral region 8 to 10μ and unaffected by any silica content it may have. This does not necessarily mean that the silica content is small, for if it were finely divided, like sand, or porous, like pumice, its radiating properties would be nearly those of a black body.

Spectroscopic examination of the violet slope of the transmission band at 8 to 14μ might reveal a deformation due to the emissivity of non-porous silicates which would escape detection by the foregoing methods. To the geologist further tests along these lines will be of great importance.

The observed distribution of light reflected by the moon shows that (1) the limb is 60 per cent brighter than the adjacent maria; (2) the center of the lunar disk is 10 to 15 per cent brighter than the limb; (3) the maria are only three-fourths as bright as the mountainous regions. The ratio of the solar energy reflected from the subsolar point to that received by it is 0.124. This may be considered to be the albedo of the subsolar point; but it should not be confused with the albedo of the moon, which is the ratio of light reflected by the whole hemisphere to that received by it. Computations made on the basis of these measurements show that the radiometric albedo of the moon is 0.093.

During the year the measurements of the relative intensities of light reflected by 50 different rocks and other terrestrial materials for different angles between the incident and reflected rays and for different parts of the spectrum were continued; in these tests a vacuum thermoelement served as receiving element and was used with and without an analyzing prism. Similar measurements on light from the moon are to be made with the same equipment and will aid in the classification of lunar surface materials.

Exposures with the new polarization quartz spectrograph placed at the primary focus of the 100-inch reflector on Mount Wilson were made by Dr. Adams on selected points of the moon's surface. The photographic plates thus obtained have not yet been measured on the recording microphotometer. Measurements of this kind yield data on the selective reflectivities and also on the polarization of the light reflected by the surface materials at selected points on the moon. Similarly measurements with the same equipment are to be made on terrestrial materials.

Satisfactory progress has been made on the preparation, by photography, of a series of maps of the moon. The apparatus for the transformation of the negatives taken of the moon by the 100-inch telescope to the standard line of sight has been set up on Mount Wilson on the site adjoining the dome of the 100-inch telescope on the north. This location is relatively free from earth tremors. The apparatus has been much improved and is housed in two special structures. It is expected that the series of moon maps prepared photographically by this method will be finished this autumn. The maps will serve as a basis for a critical physiographic study and classification of the land forms observed on the moon. The maps will be free from the personal factor that enters into all previous maps, which, without exception, were drawn by hand. In each case the degree of accuracy obtained in those maps depended on the skill of the observer in depicting the features observed through the telescope and on the quality of the telescope and photographs used. On the finished photographic maps, the latitude and longitude of each point on the moon can be read off directly with the aid of a specially prepared lunar projection chart.

Twenty-two photographs of the moon were made by Doctors Pease and Wright in September 1929 with the 60-inch telescope. During the following November, Dr. Pease, assisted by Doctors Joy and Sanford, obtained two series of photographs of selected areas on the moon with a motion picture camera at the Newtonian focus of the 100-inch reflector. The exposures were made at intervals of 8 seconds over periods of 5 or 6 hours except for short intervals when the definition was momentarily poor. Each series shows in a striking way the effect of changes in illumination due to the earth's rotation. These films were shown at the annual exhibition of the Carnegie Institution in Washington in December 1929.

Visual observations of the moon's surface with the aid of the 100-inch reflector have been made by Doctors Adams, Buwalda, Day, Pease and Wright. Dr. Buwalda has continued his work on the physiography and classification of the lunar surface features.

W. S. ADAMS
J. P. BUWALDA
A. L. DAY
P. S. EPSTEIN
F. G. PEASE
EDISON PETTIT
H. N. RUSSELL
F. E. WRIGHT (*Chairman*)

PHYSIOGRAPHY

American Geographical Society, New York, N. Y. *Completion of the study of delta of Colorado River, by Godfrey Sykes.*

Conditions in the Delta during 1929-1930

The flow of the Colorado River during the past year has been unmarked by any abnormal irregularities in volume or by the occurrence of unseasonable floods.

The readings at the Yuma gaging station of the Reclamation Bureau have been taken, as heretofore, for ascertaining the volume of water flowing on to the apex of the delta. By deducting from this quantity the amount passed through the head gates of the Imperial Canal, some seven miles below the gaging station, an approximation is obtained to the amount which actually reaches the active portion of the delta.

The peak discharge during the Summer of 1929, as measured at Yuma, was approximately 90,000 second-feet, which represents rather moderate summer flood conditions. The flow then diminished gradually to a minimum of less than 2000 second-feet early in February, when the daily requirements of the Imperial Valley absorbed the entire flow of the river for a short period.

Two moderate freshets occurred before the setting in of the customary increase of volume of the early summer, and during June a reading of nearly 60,000 second-feet was obtained, which probably represents the maximum for the present season.

The result of this moderate condition of the river has been a continuation of the building-up process, but there has been no radical change, and no channel development whatever, in the great swamp area of recent deposition which still surrounds the breaking-up point of the definite channel of the Colorado.

Passing on to this growing fan of soft alluvium, impeded by barriers of brush and dense vegetation, and losing the greater portion of its suspended load of silt with its loss of velocity, the residue of clarified water at length reaches the numerous small gathering channels which deliver it into the Hardy and so eventually into tidewater.

Nothing which seems to be capable of developing into a permanent channel through this obstructive region has yet appeared, although some means for the free discharge of this growing body of partially impounded water can not be much longer delayed—perhaps by some chance diversion down one or the other flank of the fan, or perhaps by recessive cutting from the lower margin.

The continued withholding of the greater portion of the river silt from the estuary is bringing about changes on a very large scale in the tidal channels, by upsetting the preëxisting balance between the aggradation due to the deposition of silt and the degradation due to tidal scour.

When a free channel for the river water existed across the delta, the load of silt carried annually into tidewater was approximately equivalent to a mass of dry soil one-thirtieth of a cubic mile in volume, and the tidal influx over the bar and into the estuary frequently reaches over ten times that amount, or over one-third of a cubic mile, in the course of a few hours. Now that the supply of silt is withheld, but the tidal action is still unimpaired, the accumulation of former years is being steadily swept out to sea.

With the anticipated reopening of a definite channel by the river to tidewater, a great volume of impounded silt will undoubtedly be liberated and carried downward into salt water, temporarily upsetting the equilibrium, if it has by that time been established, in the opposite direction.

This phase of the general problem therefore merits, and is receiving, the closest attention.

During the past year the construction work of the line of the Mexicali and Gulf Railroad has been carried on across the delta in a southeasterly direction, towards a contemplated seaport at the lower end of the estuary, and upon the Sonoran shore.

Several minor changes, due principally to the development activities of companies operating upon the margins of the active portion of the region of deposition, have also taken place during the year. The floods of the summer of 1929 passed temporarily beyond control in the vicinity of the barrage across the Rio Abejo, breaching the levee and doing considerable lateral cutting for a distance of several miles along the course of a newly excavated irrigation canal.

It appeared indeed for a while as though this might prove to be the expected outlet to the sea; but, as the water subsided and repairs to the levee were made, the flow was once more turned into its channel.

Other temporary diversions have taken place in the same region, but have so far been kept under control.

Method and Progress of the Investigation

Progress has been made in the investigation during the year along two general lines. Firstly, by keeping in constant touch with the actual changes and developments in the delta; through field trips, correspondence, and personal contacts with men engaged in its development; second, in the work of classifying and systematizing the notes, historical data, and other matter which have been accumulated during the previous observation of the region, and checking this material wherever possible by contemporary references in local newspapers and records.

The era of navigation upon the lower river, lasting for a period of about thirty years, is receiving especial attention, as this constitutes the longest period during which the channel was under constant observation.

The men who took part in this strenuous steamboating have now all passed away, and the scanty material which they have left in logs, records, interviews and published notes is widely scattered and not easily accessible, but an especial effort is being made to gather all such material together to supplement many personal recollections of the men themselves.

Many of the participants in the early development of the Salton basin, and those who took part in controlling the great break over the western bank of the river in 1907, are yet to be found; and, as this period was most important in determining the subsequent course of events, valuable data are being obtained from them.

The field work undertaken since the thorough examination of the active region made during the high-water season of 1929 has comprised a further general survey during February, when conditions were at the opposite extreme, and an extensive examination of the estuary and lower portion of the delta during the present summer.

Several trips to the shore of the Gulf of California and to the border region of Northwest Sonora have also been made for the purpose of keeping intact the series of meteorological observations which has been carried on for many years in direct connection with the investigation.

PHYSIOLOGY

Mussen, Aubrey, T., Johns Hopkins Hospital, Baltimore, Maryland. *Studies on cerebellar functions and localizations.*

At the meeting of the American Neurological Association in June 1930, Dr. Mussen submitted a preliminary report concerning his recent studies on the cerebellum, in which the symptoms resulting from lesions of individual lobes are compared with the reactions of the same lobes to stimulation. He showed that the stimulation reactions previously reported did correctly indicate the functions of the lobes, inasmuch as these different methods of investigation gave similar results.

This research indicates that the cerebellum always acts as a whole and that its function is made up of a primary activity which depends upon the particular lobe involved and a secondary response which is composed of the integrative synergic activity set in motion by the primary reflex.

If these investigations could be continued there is little doubt that most of those controversial questions connected with cerebellar activity would be solved, about which there is so much perplexity and the discussion of which at the present time with our limited knowledge is so unprofitable.

In November 1929, Dr. Mussen read an earlier paper on the cerebellum, before the New York Neurological Society, relating to the method of stimulation and the influence of the localized reactions in determining the course of disputed fissures, the grouping of the lobes, and the exact homology that exists between the lobes and fissures of the cerebella of the cat, monkey and man. Before the Society of Neurological Surgeons, he furthermore read a paper, in June 1930, concerning the possibility of explaining the symptomatology of the cerebellum by studying the effects produced by the experimental destruction of the individual lobes.

Russell, G. Oscar, Ohio State University, Columbus, Ohio. *Physiological cause of voice quality in singing.* (For previous report see Year Book No. 28.)

The following report concerns studies undertaken by Dr. Russell with funds appropriated by the Carnegie Corporation of New York to the American Academy of Teachers of Singing for support of a scientific study of singing, funds being payable through Carnegie Institution of Washington.

Artists and teachers of singing have long debated the question as to how the so-called "resonance of the head and nasal cavities" in "properly placed tones" might be stimulated. The question is perhaps one of the most important confronting scientists, teachers and artists concerned with voice and speech. It is obvious, therefore, why those concerned in this investigation should have chosen this problem as the one needing most immediate and intensively applied scientific study. It has, therefore, been singled out from among numerous contributions of the year for consideration in this report.

Let us first consider in summary the views at present held. Some have insisted that the velum had to be down in order that the nasal passages could be opened. Others have insisted that what they were pleased to call the sympathetic vibrations transmitted through the hard and soft palate which form the floor of the nasal passage could serve to stimulate the cavities in question. This has undoubtedly been one of the most strenuously debated moot questions confronting the profession. Practically no evidence of an objective or experimental nature had been produced. The debate had to be a polemical one, therefore, and was dependent largely on *a priori* reasoning, or what each individual thought he felt. Now and again an individual was found in whom the X-ray showed a lack of the antrum on one side or a congested frontal sinus; and almost invariably where he lacked the proper ring to his voice, the fault was ascribed to this condition. So far as the marshalling of a series of cases of this kind and the carrying through of a consistent X-ray study of all types of voices were concerned no evidence was forthcoming. A number of individuals had announced the observations they had made with the stethoscope. Among these was West, whose conclusions were negative. Many teachers of voice thereupon obtained stethoscopes, but insisted their observations did not confirm his. Unfortunately the preconceived theory and mental set of the observer very largely conditions what he hears.

It was obvious, therefore, that more objective and conclusive evidence was necessary. Our first preliminary tests made with the stethoscope indicated why observations made therewith could give such widely varying results where competent observers justifiably disagreed, yet where the two so conflicted as to make the truth of each incompatible. It was shown at the beginning of our investigation that the stethoscope responded to air vibrations as well as those made by surface contact. And it is obvious that the loudness of the air-conducted vibration at the mouth of the cavity will be much greater than those which have to be transmitted through the walls of the cavity. It was not possible, therefore, to adequately compare the energy of the laryngeal tone transmitted through the cartilages of the larynx and walls of the throat with those of the same source after they had passed through the mouth and nose and were obtained at the orifices of the buccal cavity or nostrils. Those taken at the latter point would be air-transmitted and might well appear to have considerably more so-called "resonance" or energy than the surface-conducted ones taken over the larynx proper, in spite of the fact that the contrary might be true.

What was needed was evidently a piece of apparatus which would pick up nothing but surface vibration and would be relatively non-responsive to those transmitted through the air. Means of objective registration and measurement of the same was likewise required. That is, a measurement of the carrying power of the voice was called for.

While some artists and teachers insisted that a very softly produced tone might possibly have greater carrying power than a very strong one, this impression was assumedly due to their feeling as to the amount of effort involved in the production of the tone rather than the energy actually present. Physicists and scientists generally insisted, and proved by experimentation, that the sound possessing the greatest amount of inherent energy was the one having the greatest carrying power.

There is a possibility that the voice quality involved in varying partials present might well account for much of the discrepancy between the observation of the artist and the facts proved by the scientist. The preponderant energy in a complex tone could of course be shifted to differing partials; besides there are many ways in which the apparent carrying power of a complex tone might vary by reason of the pitch involved. It will suffice to indicate one, the well-known fact that the ear favors certain pitches. Many others might be cited, but that is not a question for us to consider.

Now the comparative energy in two tones of identically the same pitch is manifest in the amplitude or the extent of the oscillating excursion they would produce if they set a needle or pendulum to vibrating. It is this curve which we use, therefore, to graphically portray the energy involved. But if the pitch varies, correction must be made in order to compare the energy involved in any two tones of such differing pitch; since the higher the pitch, the less is the amplitude or excursion of the needle produced, even though identically the same energy is involved. Many attempts had been made to utilize this graphic process in a study of this type; but the work involved in making these corrections, necessary by reason of variations in pitch, made the experiment too laborious and prohibitive.

A consideration of all these factors finally led to the assembly of a piece of apparatus which we called, for purposes of description, the *Sonometer*. This assembly uses a surface-conduction transmitter which, like its sister, the bone-conduction receiver, has vibration characteristics with little affinity for those which must necessarily be air-conducted and decided stimulus for those which are transmitted by surfaces. The terminals from this unit lead through a high quality amplification circuit to a recording dial graduated in sensation units or decibels, in such a way that the deflection of its needle will show the amount of energy or carrying power involved in the complex tone, regardless of the pitch concomitant present therein. It is obvious that if with this surface-conduction transmitter a comparative measurement is made of the energy or carrying power present in the tone as it emits from the larynx and that of the same tone after it comes in contact with any sinus or other head, nasal, or chest cavity—if the carrying power is increased by any one of these latter cavities—the energy deflection of the needle on the dial will be greater when the surface-contact transmitter is placed over the cavity than when placed over the larynx.

This was the method used in obtaining the facts indicated in the summary below, where the individual artists beginning with Gigli are reported upon. Before we proceed with a consideration of these facts, however, it would probably be wise to consider the views now held. Since our experiments as indicated are negative and seem to present conclusive proof contrary to these conceptions, it might be just as well to give a citation of certain physiological facts which it appears support the conclusions of the present study, and would have disproved the generally current view if given adequate consideration.

We are talking of what artists, teachers of the voice, and others have designated "resonance." A voice with good carrying power is said by them to be "resonant." The terms "correct placement" or "proper placing of the voice" have been used by many in this connection, but protested by others. All scientists agreed that the voice could not actually be "placed," but many agreed with the singing profession in the concept involved, if not in the actual usage of the term "resonance." This latter term as used by scientists does not necessarily imply that the tone which is resonant should have good quality. A tone with resonance or amplification, due to its wave train coming in contact with a cavity having the same natural frequency period, might well be screeching, strident, guttural, nasal, or otherwise disagreeable. It is obvious, therefore, that the terms resonance or resonant as used by the voice profession, being applied only to good quality with adequate carrying power, was never scientifically justifiable. So far as the quality involved was concerned, the term "ringing" would have been much better. Above all, however, it was applied to a tone with good "carrying power." Since that involves energy or intensity, this aspect of the tone could therefore be designated as intense, and the tone itself be called an "intense tone."

Now the question which confronts us is: Does the carrying power or what has been called "resonance" in a well-trained, or what some call "well-placed tone" trace its characteristics to a function of the nasal, head and chest cavities?

Let us consider some of the physiological and physical facts. Where the *velar passage* is either completely opened or closed, the nasal passage itself can have but little power of changing its own natural period of resonance. This means that it could serve to accentuate but one single solitary pitch providing no constriction in the *turbinates* and muscles near the outlets be utilized, and that necessarily follows if the tone is to be kept free from nasality. Each *sinus*, or open bony cavity in the head, is even more rigorously limited, since it has but one single pitch to which it could possibly respond in resonance without any power whatever of varying this from moment to moment; but aside from this fact, it may be pointed out that no one of them is provided with an opening out into space large enough for it to function as a resonator. The *lungs* themselves which occupy the chest *cavity* are so broken up into their infinitesimally small *alveoli* and are so soft and spongy that they could not be considered as having the ability to function as a resonator, even if they were located above the vocal cords or source of sound stimulus. The *trachea* and *bronchi* with their *bronchioles* are the only cavities which might be considered to be of such a nature as to permit their function as resonators, if they had been properly located in relation to the source of sound.

If these cavities functioned as resonators to add greater carrying power and better quality to the voice of an individual, one might expect the best voices from those with large and well-developed sinus cavities. The maxillary sinuses and the two parts of the frontal sinus lie so close to the outer prominences on the face that some have assumed we could judge their comparative size in individuals by the prominence of these ridges represented in the cheek bones and the supraorbital area, including the superciliary ridges and nasal eminence. Zuckerkandl thought there was no necessary relation between a prominent superciliary ridge and a capacious frontal sinus, or the reverse. But from an examination of 125 preparations, Lothrop formed the opinion that "in general it is fair to conclude that the more prominent the supraorbital area, the greater the probability of the presence of well-defined sinuses." One needs only to look at great artists to discover that good voices can not be measured in this way.

Then, too, it is not amiss for us to note the fact that these sinus cavities are, generally speaking, substantially smaller in women than in men, yet there are as great singers among women with good carrying quality in their voices as there are among men.

It may also be of interest to observe the fact that all of these sinus cavities do not exist at all, or only in a rudimentary form at first. The maxillary reach their full development at about the age of twelve years. The frontal are seldom evidenced before the seventh or eighth year; they increase rapidly with puberty and reach full size only at about the twentieth year. The ethmoidal likewise fail to reach their full development before the twentieth year, though they may commence around the age of four or five. The first appearance of the sphenoidal is given by different authors as at the third (Steiner), seventh (Lawrence), or twentieth year (Tillaux). These facts are not without significance since we know that young people regularly have voices of great carrying power, in spite of the lack of these so-called resonance cavities.

It is surprising, therefore, that these scientifically unsupportable ideas in regard to the function of these cavities as resonators should have received credence, particularly among those with even the most elementary knowledge of the acoustical principles involved. But they were so widespread that it had not occurred to our staff to question their validity. It was only by an attempt to make a systematic examination of each and every theory involved in the general question as to "what the physiological causes of good and bad voice quality are," that we came to assemble definite evidence on this point. So all the members involved in the investigation were frankly surprised and skeptical when the first evidence was forthcoming. Our proof, however, that not even the nasal and bony head cavities served to function as resonators, or in other words, to give the voice better carrying power, may be looked upon as perhaps the most outstanding contribution of this year's work on this general problem. However, we may hasten to say that this evidence does not prove that these cavities have no function at all. It merely says that the carrying power of the voice can not be ascribed to them and hence that they can not be called resonators in the strict sense of the word; but they undoubtedly serve to alter the concomitant of partials present in the complex tone. Hence the mouth, nasal, head (and chest) cavities could undoubtedly all be more justifiably called modifiers, which they are, rather than resonators.

Tests were made with our *Sonometer* on some of the outstanding operatic and concert stars, not only of the country but of the world.

Our Experimental Evidence

In the case of Gigli, the Metropolitan tenor, no question can arise as to either the resonance in his voice or its carrying power; yet the deflection of the needle on the dial shows very considerably greater loudness and energy in the tone when the contact is made over the larynx, than when the registration is taken from over the maxillary, frontal sinus, or nasal bridge. The loudness registered at the tip of the chin, over the side of the soft cheek wall of the mouth or back jaw-bone is much greater than at any point on the cranium or head; yet probably no one would be so presumptuous as to say that resonance or carrying power were given to the tone by reason of the influence of these areas. Even the deflection of the needle at these points showing the carrying power of the tone is substantially less than that taken from over the larynx or source of the voice tone. Johnson, another Metropolitan tenor with a voice of undisputed carrying power and resonance, yielded on test results in all essential respects confirmatory to those indicated for Gigli. The same may be said of Jagel. The deflection taken when registration was made by placing the surface-contact transmitter over the center lung area in stethoscope fashion showed practically no deflection whatever, on even the very low tones within their customarily used range. As the pitch rose, there were frequency bands where the deflection over one or the other of the head areas was greater than in other bands. At no time, however, was this sufficient to show the tone as having greater carrying power or energy after having struck these so-called sounding-boards or resonators, than when it was emitted from the glottis.

Bori, Müller, Melius, Romaine, Vreeland, and a number of other sopranos likewise having voices of undisputed carrying power and so-called resonance, all yielded much the same results, and in all cases the tone showed much greater energy at the point where it emitted from the larynx than was manifest after it was passed through any of the vocal or nasal cavities or encountered any of the so-called sinus resonators and palatal or cranial so-called sounding-boards.

Tibbetts, Werrenrath, Althouse, with voices of like recognized carrying power and resonance, all yielded confirmatory evidence. And in all cases the laryngeal tone showed greater inherent power immediately after leaving the glottis than could be registered by the tone deflected from any of the head or chest areas mentioned above.

Gustaffson, the well-known Metropolitan basso, Valenti and Stephens, are the only bassos I had to report. In all cases the evidence confirmed that above mentioned. The inherent energy picked up by the transmitter was very much greater at the source of voice production than after the sound had passed through or struck any of the head cavities and areas above indicated. In these subjects we paid particular attention to the registration on low tones manifest from areas over the chest. While practically no deflection was noticeable from over the middle of either lung and even over the trachea immediately under the vocal cord, the power inherent in the transmitted tone was considerably less than that above the vocal cord; yet a noticeable difference between the carrying power of the low pitched tone picked up from over the trachea and the high pitched tone was made manifest. I do not know that one would be justified in drawing conclusions from this observation made on such a small number of subjects. But this evidence would seem to indicate that this tube placed under the glottal stimulating source may serve a purpose in altering the so-called chest tonal quality. It is evident that this purpose is not to give it greater carrying power, but only to change the quality, in which case it probably served to accentuate the lower partials. In this connection it is interesting to note that the *cushion of the epiglottis* and the *cartilages of Wrisberg* above the vocal cord tend to approximate in the production of the very lowest note of the individual's voice. This narrowing of the opening above the vocal cord may serve to fling the tone back on itself and down into the trachea with some such result as that indicated.

I am very sorry I have no outstanding contraltos on whom I can report. This represents but one aspect of this year's investigations. By reason of its outstanding importance in a consideration of the general question of "what the physiological causes of voice quality differences are," even though its evidence be negative, I have considered it the most outstanding contribution in this year's experiments. So I am stressing it. On an average between ten and twenty X-ray exposures have been made on all the artists above indicated, as well as on a number of others. All such X-rays were synchronized with high quality sound records, making it possible to check back on exactly what the pitch and voice quality was at the instant of X-ray exposure. These photographs show the exact position of the lip, tongue, velum, larynx, hyoid bone and exact diameter of the lip, velar and laryngeal opening. In most cases they likewise give the exact length of the vocal cord, and therein present some of the first definite evidence on the vital subject ever obtained. It will naturally be some time, perhaps decades, before all the mass of experiments thus obtained on practically all of the famous operatic and concert stars in this country, students and others of more modest voices, as well as on many deaf persons and others of recognized very bad voices, is all compiled, organized, measurements made, and the whole studied and interpreted.

Laboratories were established at 11 West 49th Street, New York City, under J. Oscar Russell as Director, and with the cooperation of operatic stars and members of the American Academy of Teachers of Singing, directed by a committee consisting of Percy Rector Stephens, chairman, Wilfred Klamroth, secretary, Walter Bogert, George Fergersson, Gardner Lamson and Frederick H. Haywood, all of New York City. Caperton Horsley, C. J. Kraissl and Miles G. Goff served as laboratory assistants. The Eastman Research Laboratories of Rochester, New York, collaborated in the work, directed by Clifton Tuttle.

PSYCHOLOGY

Bingham, Harold C., **Yale University, New Haven, Connecticut.** *Study of Gorilla behavior in Parc National Albert, Africa.*

In January 1930, Dr. Harold C. Bingham, Research Associate of the Institute of Psychology of Yale University, and his wife, returned from Parc National Albert in Africa where, under the joint auspices of Carnegie Institution of Washington and Yale University, they had spent several months in observation of the behavior of the gorillas which there live a free life though protected from hunters by royal decree.

For several years Professor R. M. Yerkes of the Institute of Human Relations, Yale University, has been engaged in the study of Primates, an order of mammals which includes man and the apes. In the initiation of his program, colonies of chimpanzees were assembled and studied in Cuba and at Yale University. In further support of this program of investigation, announcement was recently made that Yale University, through the assistance of the Rockefeller Foundation, had acquired nearly 200 acres of land in Florida where Professor Yerkes will establish a station for the breeding of anthropoid apes and their scientific study.

In the capacity of Research Associate, Dr. Bingham has been closely associated with Professor Yerkes in study of chimpanzees and in outlining the program of expansion. Dr. Bingham's study of gorilla behavior in Parc National Albert, made possible through the cooperation of Carnegie Institution, was therefore, in part, supplemental to the researches begun in the Yale laboratory. Indeed, the expedition was undertaken not only to obtain authoritative information about the behavior of free-living gorillas, but also to investigate the feasibility of coordinating such observations with lines of anthropoid research already established at Yale and with the program contemplated for the anthropoid station to be established in Florida.

During the time the expedition was in the field, frequent contact with gorilla groups was established, contacts which were maintained for considerable periods. These groups were followed as they fed their way along and observations made on the nests, feeding habits, social responses, nomadic behavior and the traits of individual animals. Still pictures and moving pictures were taken whenever conditions favored. Much information was also secured as to the nature of the environment in which the gorillas range. Particular attention was given to the plants upon which the animals feed and a number of specimens were brought back for examination and identification.

Pearson, Karl, and Henry A. Ruger, Teachers College, Columbia University, New York, New York. *Studies on the theory of surfaces.* (For previous reports see Year Books Nos. 27 and 28.)

The following report is submitted as the result of continued studies undertaken with appropriation of funds by Carnegie Corporation of New York to the Carnegie Institution of Washington for support of Generalized Frequency Surface Research.

The first of the statistical studies in this series is nearing completion. It is a continuation of the reduction of certain anatomical and motor data reported in volume II of The Annals of Eugenics. The original measurements on a population of 7000 males with a wide age range are due to Sir Francis Galton. The Annals of Eugenics paper presented growth, or age, curves for sensory and perceptual as well as for anatomical and motor characters. The present investigation has involved the transformation of the original scores into standard scores age—corrected for means and standard deviations. The eight traits selected involved 28 pairs. The two-way frequency distributions corresponding to each of these pairs have been set up both for the entire population of 7000 and for each of the component age groups. There are 28 age groups covering a range of 75 years and with an average population of 250. The moments requisite to the computation of correlation coefficients and correlation ratios have been obtained for the total population spreads and also the separate age group distributions, of which there are 784. Correlation coefficients have been computed for almost all of these, but the correlation ratios and non-linear regressions are yet to be secured. Higher product moments for the total population surfaces are now being computed. The work done is preparatory to a study of the frequency constants for the entire population and their relation to those of the component age groups.

SEISMOLOGY

REPORT OF THE ADVISORY COMMITTEE

(For previous reports see Year Books Nos. 20-28)

It is well to bear in mind that the Carnegie Institution of Washington entered upon its plans for seismologic investigations quite tentatively. It recognized the need for greater attention to the problem of earth movements on the American continent, but stood in no way committed to any particular pathway of approach to it. When Mr. Harry O. Wood offered his plan (1916) for a rather thorough study of local earth movements in California there appeared to be no agency which was really prepared to undertake the task. It was therefore quite obvious that the first progress must be tentative in a field in which American participation had been limited.

As has been recorded elsewhere (Year Books 20 et seq.) the first step of the Institution was to invite the Advisory Committee in Seismology to pass upon the project which had been submitted to it (Mr. Wood's). Upon receiving a favorable report of it, the same Committee was requested to take such steps as it deemed advisable to inaugurate studies of the California fault zone. The early efforts of the Committee brought out into plain view a number of conspicuous deficiencies, (1) in our knowledge of the region, (2) in the equipment available to study it. There are great faults in California, some of which were known to geologists and several of which had been active within historic time. The San Andreas fault for example had been traced from Point Arena to the Mexican Boundary, a distance of some 600 miles, with conspicuous evidences of recent activity throughout most of its length; the Haywards fault to the east of San Francisco Bay had been destructively active in 1868, the great Owens Valley fault was very active in 1872; and in southern California, in addition to the San Andreas fault, the San Jacinto fault and several others were known to have been recently active. The geology of the fault zones both north and south had not been studied in any considerable detail except in the San Francisco Bay region by Branner and Lawson (1909). Of first-order triangulation upon a scale sufficiently large so that the direction and amount of any movement occurring in the fault zones could be accurately measured, there was also very little. The continental shelf marking the abrupt termination of the continental mass to the westward was known to exist but had not been accurately located. The height of Mount Whitney had been twice measured and was suspected to be the index of a vertical movement which perhaps included the entire Sierra block, but this was hardly more than a speculation.

These details may convey to our minds the state of our knowledge, or lack of it, in a region which had been marked throughout the civilized world as the seat of the great San Francisco earthquake of 1906 and of a number of other destructive shocks both before and after that year. The Committee was therefore unanimous in its opinion that such a problem deserved study both from the viewpoint of the student of the crust of the earth, its history and development, and of the man in the street who desired to know with what security he could continue living in those regions of the

West Coast which had been lately visited by destructive shocks. It was to this situation that the Advisory Committee invited the attention of the President and Trustees of the Carnegie Institution of Washington and from them received approval of its plan to see what could be done to add to our knowledge in these directions.

In 1929 after eight years of such effort, supported liberally by the Trustees of the Institution, the Advisory Committee wished to meet for the purpose of discussing (1) the evidences of success of the efforts which had been put forth during this period of time, (2) whether or not it was desirable to continue such efforts, (3) whether perhaps the progress made may not have been sufficient in amount or character so that it might more appropriately be carried on by some local agency in the region most interested in such information.

It should perhaps be explained that the Advisory Committee in Seismology is country-wide in the distribution of its membership. Its operations had accordingly been carried on during the eight years by sub-groups meeting occasionally, either east or west as opportunity offered, by correspondence and by the more or less consecutive efforts of the Chairman. Accordingly a Conference of the full Committee was called to meet at the Seismological Laboratory in Pasadena in October of 1929. To this conference were bidden, beside the members of the Committee, two of the most distinguished students of seismology abroad (Messrs. Harold Jeffries of Cambridge, England, and Beno Gutenberg of Frankfurt, a.M., Germany), the President of the Jesuit Seismological Association, Dr. J. B. Macelwane, S.J., and certain representatives of other institutions known to be interested, Mr. L. H. Adams of the Geophysical Laboratory, Washington, Professor Perry Byerly, University of California, members of the staff of the Mount Wilson Observatory, and California Institute of Technology (including primarily of course the Staff of the Seismological Laboratory) and some others. There was laid before this group the full record of progress in American seismology in which the efforts of the Committee had a part. These included among the more general activities the fault map of California prepared in collaboration with the Seismological Society of America; the contour map of the ocean floor between the San Francisco Bay region and the Mexican boundary extending seaward to a depth of 12,000 feet, in collaboration with the Navy Department; the considerable number of problems undertaken in collaboration with the U. S. Coast and Geodetic Survey, which include daily position observations at the latitude station at Ukiah, California, primary triangulations of the highest precision over the entire earthquake zone from Point Arena to Mexico tied in with the more stable regions to the east of the Sierra Nevada Mountains by three separate triangulation nets extending eastward respectively from the coast to beyond Reno, Nevada, in the north, from San Louis Obispo to Salt Lake at the midway point, and along the Mexican boundary to American Peak in the Colorado River basin at the south. This system is supplemented by local triangulation (averaging one monument to the mile) of the highest precision, crossing the fault zones at right angles in the region immediately south of Los Angeles and immediately north of the City of San Francisco. There is probably no region in the United States in which provision for the detection of horizontal earth movement through the location of bench marks at critical points is more completely developed than in the earthquake zone of California. There has also been completed through the collaboration of the Coast and Geodetic Survey a group of lines of precise levels which likewise cross the known faults of the region in such a way as to give greatest emphasis to vertical movement in case it should occur there. By no means least of these activities is the splendid impetus given to the geological investigation and mapping of the fault-zone region by the work of Levi F. Noble and W. S. W. Kew of the U. S. Geological Survey, supplemented locally by the geological faculties and students at Berkeley and Stanford Universities.

There was also laid before this assembly at Pasadena the complete records of the Seismological Laboratory established in collaboration with Mount Wilson Observatory and the California Institute of Technology and operating as a central station for the detection, record and study of local earth movements in southern California and vicinity and the development of new apparatus and methods since 1923. With this Laboratory are associated six outlying branch stations fully and uniformly equipped with automatic horizontal-component instruments and radio-timing equipment, the records of which are sent weekly to the central station for register and interpretation. These sub-stations are located at Santa Barbara, Riverside, Mount Wilson Observatory, La Jolla, and at Haiwee and Tinemaha in the Owens Valley.

In addition the members of the Committee and its guests were made acquainted with the details of operation of the central laboratory in Pasadena and the instruments developed there, as well as with one of its sub-stations (Santa Barbara). They were also given opportunity to travel over the surface outcrop of the San Andreas fault for a distance of some sixty miles northwestward from San Bernardino. The daily program of the meeting printed below will convey a comprehensive idea of the subjects covered by the group in round-table conferences which, by their informality, gave the fullest opportunity for adequate discussion of European and American methods as well as for an exchange of views of crustal movements and characteristics as revealed by the efforts of European and American students of the subject. No point of major interest escaped attention in the two weeks covered by the conference.

PROGRAM

WEDNESDAY, OCTOBER 2—*Morning Session*

Address of Welcome, DR. ARTHUR L. DAY, Carnegie Institution of Washington.

The Relation of Some Recent Developments in Physics to Seismology, DR. R. A. MILLIKAN, California Institute of Technology.

Inspection of the Seismological Laboratory, its equipment, and activities: routine service, torsion seismometers, optical systems, recording drums, driving systems, mechanisms and methods for time-keeping, provisions for time-comparisons, radio-code time-synchronization at all stations, etc.; special experimental and research equipment.

WEDNESDAY, OCTOBER 2—*Afternoon Session*

Outline of Local (Southern California) Geologic Conditions and Structures, Location of Important, and Minor, Geologic Faults and Their Status of Activity so Far as Known, DR. J. P. BUWALDA.

Location of Seismological Stations, with Reference to Faults, Their Location and Courses, and to Surface Conditions; granite at Riverside, Mount Wilson, and Pasadena; stream alluvium at Santa Barbara; beach deposits at La Jolla; tuff at Haiwee; and rhyolite at Tinemaha; description and explanatory comment, MR. HARRY O. WOOD.

Epicenters, and Epicentral Tracts, hitherto located. Degree of accuracy attained in determination of position, of depth, and their relation to faults; discussion and explanation, DR. CHARLES F. RICHTER.

THURSDAY, OCTOBER 3

Excursion to San Andreas Fault, led by DR. J. P. BUWALDA.

FRIDAY, OCTOBER 4—*Morning Session*

Statement of our Problem: to locate epicenters, and the position and depth of hypocenters, of all shocks above a certain small minimum of energy which originate in our local province, say, within five hundred kilometers, and to determine their relationships to the geologic faults and the geologic activity as well as possible; to carry on studies of wave-speeds, wave-paths, wave-transformations, energy-partitioning, etc., etc., both to advance knowledge generally and to improve methods for locating epicenters and hypocenters by instrumental means, as well as by field methods and in other auxiliary ways. Secondarily, to register distant earthquakes and contribute data and studies to this part of the field of seismology.

There are involved: (a) effects of the space-relationships of the geologic units, and the variable physical conditions which they introduce, (1) on the distribution of surface intensity and (2) on seismographic instruments mounted upon crystalline rock, sedimentary rock, and loose aggregates; (b) competent knowledge of the geologic materials, conditions, and structures, obtained either by field investigations, or by the interpretation, analysis, and measurement of the seismograms; (c) consideration of the instrumental requirements and desiderata, and the number and distribution of the stations necessary for effective progress, DR. ARTHUR L. DAY and MR. HARRY O. WOOD.

FRIDAY, OCTOBER 4—*Afternoon Session*

Consideration and Discussion of Selected Seismograms:

(a) ordinary typical records;
(b) records presenting special features or problems, with respect to (1) action at the origin; (2) mode of transmission; and (3) instrumental response, MR. HARRY O. WOOD and DR. CHARLES F. RICHTER.

SATURDAY, OCTOBER 5—*Morning Session*

Consideration and Discussion of Selected Seismograms (continued), MR. HARRY O. WOOD and DR. CHARLES F. RICHTER.

SATURDAY, OCTOBER 5—*Afternoon*

Short local field excursion to inspect faults and geologic structures in the neighborhood of Pasadena, led by DR. J. P. BUWALDA.

MONDAY, OCTOBER 7—*Morning Session*

Response of the Seismometer; Interpretation, Theoretical Considerations, and Practical Requirements and Desiderata. The nature of the disturbance which reaches the seismometer, its form, duration, etc. (a) in the case of a simple disturbance at the origin; (b) in the case of a complicated prolonged disturbance at the origin. The essential, and desirable, instrumental characteristics to detect and register the disturbance at the site of the seismometer, DR. JAMES B. MACELWANE, S.J.

MONDAY, OCTOBER 7—*Afternoon Session*

Response of the Seismometer, etc. (cont.), DR. JAMES B. MACELWANE, S.J.

TUESDAY, OCTOBER 8—*Morning Session*

General Geologic Considerations; production of Crustal Strain; Mode of Shock Causation; Elastic Rebound; Discussion, DR. HARRY FIELDING REID

TUESDAY, OCTOBER 8—*Afternoon Session*

Seismic Wave-Transmission as affected by Geologic Structures, Materials and Conditions; Refraction, Reflection, Diffraction, Absorption; Amplitudes, Periods, and Energy Relations; Discussion, DR. HAROLD JEFFREYS.

WEDNESDAY, OCTOBER 9—*Morning Session*

Seismic Wave-Transmission, etc. (continued). Consideration of isostasy, DR. HAROLD JEFFREYS.

WEDNESDAY, OCTOBER 9—*Afternoon Session*

Instrumental Methods for Determining Epicenters and Depths of Focus; Graphic and Analytic Methods of Reduction; Transmission-Time Tables and Diagrams; Criteria for Recognizing Phases, Wave-Groups; Accuracy of Time Determinations Required; Discussion, DR. BENO GUTENBERG.

THURSDAY, OCTOBER 10

Excursion to Santa Barbara to inspect the seismological station there, and faults and geologic structures en route, led by DR. J. P. BUWALDA and DR. W. S. W. KEW.

FRIDAY, OCTOBER 11—*Morning Session*

Methods for Determining Epicenters based on Field Investigations, Intensity Scales, Intensity-meters; Geologic Effects, Structural Effects, Household Effects, and Modifying Conditions; Construction and Use of Isoseismals; Discussion, MR. HARRY O. WOOD.

FRIDAY, OCTOBER 11—*Afternoon Session*

Additional and Auxiliary Instruments, Apparatus and Equipment for General and Experimental Purposes; Seismometers of Special Kinds; Clinometers; Intensity-meters; Discussion, DR. J. A. ANDERSON and MR. HARRY O. WOOD.

SATURDAY, OCTOBER 12—*Morning Session*

General Discussion, Review and Summary.

SATURDAY, OCTOBER 12—*Afternoon*

Short Local Excursion to Neighboring Places of Interest.

MONDAY, OCTOBER 14

Meeting of the Advisory Committee in Seismology of the Carnegie Institution of Washington.

Outline of work accomplished, in progress and under consideration.

TUESDAY, OCTOBER 15

Excursion to the Mount Wilson Observatory.

WEDNESDAY, OCTOBER 16—*Morning Session*

Business Session of the Advisory Committee in Seismology.

WEDNESDAY, OCTOBER 16—*Afternoon Session*

Business Session of the Advisory Committee in Seismology.

At the close of the conference three of our guests were invited to meet in sub-committee and to present to the Chairman constructive criticism either of the methods followed, or of the results attained, or any recommendations for future activity with which they may have become impressed during the progress of the conference. Below is printed the brief report of this committee.

REPORT

In general the results obtained have justified the expenditure.

It would be a great mistake to give up the program at this time.

If any change were made which would even result in serious curtailment of the program it would be unfortunate.

It is clear that in the early stages of the program great emphasis had to be laid on instrumental development. Instruments are now available which are at least as satisfactory as any in existence. But further instrumental problems still await solution. These are, for example, the development or selection of

(1) A satisfactory vertical-component seismograph.
(2) Strong-motion seismographs.
(3) Very short- and very long-period seismographs.
(4) A satisfactory method of obtaining correct absolute time and synchronization.
(5) A reliable precision drive for the drums.

We would suggest that precise pendulum clocks be provided for the stations to give correct time marks for the sensitive seismometers, and that an emergency timing system be sought for the strong-motion seismographs. We would also suggest that if it be feasible minute-to-minute radio signals be provided either through private or governmental broadcasting stations.

It is felt that the time has now arrived for a more comprehensive study of wave transmission and of groups of earthquake records in this region. To this end the number of stations ought to be increased since those now operating do not furnish sufficient data for the fundamental problems of wave velocity, depth of focus and crustal structure. The cooperation of other stations at distances up to one thousand kilometers is needed. For example, it would be desirable to secure the continuous operation of the existing stations at Reno and Salt Lake City. It is strongly urged that new stations be established on the islands to the westward and in the desert country to eastward of the present group. One or two stations ought to be located to the northward between the present group and that under the direction of the University of California.

In order to obtain the best results in study of the large number of records that will probably become available, the laboratory should endeavor to secure additional personnel who have proper background and training and who are fully acquainted with the methods of the modern study of near earthquakes.

In addition to the studies carried on in the stations it is recommended that the widest possible scope be given to studies in the field. It is desirable that no source of information in regard to perceptible earthquakes be neglected. Besides the data which are assembled through questionnaires or gathered by a competent observer, it is to be wished that instrumental information be made available through the development of some type of intensity meter.

(Signed) HAROLD JEFFREYS.
BENO GUTENBERG.
JAMES B. MACELWANE, *Chairman.*

In consequence of this rather intimate scrutiny of the results of its efforts the Advisory Committee felt some confidence in the soundness of its progress, and in the business meeting of the Committee, with which the gathering at Pasadena closed, it voted to recommend the continuance of the present program without essential modification for a period of years. It voted also to commend to the attention of the Trustees of the Institution the specific recommendation of the sub-committee of our guests, particularly the one advising a greater number of stations and more complete instrumental equipment, with which the Advisory Committee is in fullest accord. The conference was brought to a close on Wednesday, October 16.

GEODETIC WORK DONE IN CALIFORNIA BY THE U. S. COAST AND GEODETIC SURVEY DURING THE YEAR JULY 1, 1929, TO JUNE 30, 1930[1]

The U. S. Coast and Geodetic Survey has continued its operations, under the appropriation made by Congress to carry on geodetic operations in regions of seismic activity, during the fiscal year ending June 30, 1930.

The observations to reproduce the old triangulation having been completed several years ago, it was decided that it would be desirable to have comparatively short arcs of triangulation cutting across the general directions of the fault zones. The idea was that there should be a main chain of triangles or quadrilaterals, with many supplemental points which could be located close to the fault zones that were crossed by the triangulation. At the close of the last fiscal year, work was in progress on an arc of triangulation from Newport Beach northeastward to the vicinity of Lucerne Valley. This arc has been completed and the northern end of it has been extended by a short arc of first-order triangulation, running directly northward to a connection with the arc that runs eastward from the vicinity of San Luis Obispo into Nevada. The new work thus forms a closed loop and the resulting geographic positions will be based upon those of the previously existing triangulation stations with which the arc is connected.

Early in the fall of 1929, the observers of the U. S. Coast and Geodetic Survey began work on a short arc of triangulation which extends eastward from Point Reyes. This arc will cross several fault zones and near each zone will be placed triangulation stations. The main chain of triangles will be tied into the already adjusted triangulation net of the country and the geographic positions of the intermediate stations will be interpolated. The observations for the supplementary stations will be secondary in character but, even so, the resulting geographic positions will be determined with high precision. In many cases the lines are quite short, from one to five miles in length, and the requisite degree of accuracy can be obtained by making about half the number of observations over these supplementary lines that would be required in the principal chain of triangles. Fog and haze seriously interfered with the work on the Point Reyes arc and prevented its completion before winter. Observations were resumed in the early spring of 1930 and the arc was nearing completion at the end of June.

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[1] Dr. William Bowie.

When the observations have been completed on the Point Reyes arc, work will be begun on an arc of a similar nature which will run eastward from the vicinity of Monterey Bay. For this new arc the principal stations will be connected directly with the existing triangulation net of the country.

It is planned to re-run about 158 miles of first-order leveling in the Imperial Valley, joining El Centro with Jacumba, Niland and Yuma. Leveling was run over those lines in 1926, 1927, and 1928, but it is now felt that some disturbance of elevations may have resulted from the recent earthquakes, reported as having occurred in the Imperial Valley near the line of levels in question. The releveling is expected to be done in the fall of 1930.

It is probable that the observations for the variation of latitude may have an important bearing on certain geophysical investigations and problems. It is interesting to note that Congress has authorized the reopening of the variation-of-latitude station at Gaithersburg, Maryland. That point was one of the stations of the international group from about 1900 to 1914, when it was discontinued. There have been uninterrupted observations at the variation-of-latitude station at Ukiah, California, since 1900 and now we may expect to have observations made at both Ukiah and Gaithersburg for an indefinite time. The observations will be conducted by the U. S. Coast and Geodetic Survey, since the interest in the two stations in question was transferred to that Survey by the old International Geodetic Association after the close of the World War. The results of the observations made at the stations in the United States will be sent to Dr. H. Kimura of Japan, who is President of the Joint Committee on International Variation of Latitude, which is composed of members of the International Astronomical Union and of the Section of Geodesy of the International Geodetic and Geophysical Union.

The appropriation for the regular geodetic field work of the U. S. Coast and Geodetic Survey has been increased from $88,600 to $316,624 in order to carry out the plans of President Hoover for the more rapid completion of the topographic mapping of the United States. As is well known, the triangulation and leveling executed by the Coast and Geodetic Survey form the basis for the topographic mapping. With the increased appropriations, the Coast and Geodetic Survey will be able to carry on its geodetic operations more rapidly. This is of interest to the seismologist because every line of first- or second-order leveling and every arc of first- or second-order triangulation form the basis for the determinations of the earth movements of the future. The plan followed by officials of the Coast and Geodetic Survey calls for such an amount of leveling and triangulation as will insure that no place in the United States will eventually be more than about 25 miles from a bench mark or triangulation station of first- or second-order accuracy. If the appropriations in future years are not decreased from the sum made available for the fiscal year 1931, it is expected that in about twelve years very little of the first- and second-order control surveys of the country will be uncompleted. The intermediate areas will be controlled by third-order leveling, triangulation or traverse for the immediate needs of the topographic and other engineers.

WORK OF THE SEISMOLOGICAL LABORATORY[1]

Routine registration at the new stations in Owens Valley began at Tinemaha on September 4, and at Haiwee on September 11, 1929. As in the case of all the other auxiliary stations, no vertical-component seismometers are yet available at these stations. Also, up to the present, the Warren motors which rotate the recording drums have been operated by the ordinary commercial alternating current. Frequency-control apparatus will be installed here as soon as it is available. These stations have demonstrated their value already in resolving uncertainties regarding places of origin. They also extend usefully our range of information; at the same time they bring unsolved problems to notice. They have been of assistance in the study of shocks originating considerably to the north of the Southern California province, contributing data for correlation with that of the stations in Central California operated under the supervision of the University of California.

Despite diligent effort, no substantial progress has been made in securing stations at Fallbrook in San Diego County, or on Santa Catalina Island. It has become evident that both these and several other stations are greatly to be desired for the study of important fundamental problems indicated by the complexity of registration in the so-called "preliminary tremor" of the seismogram.

The routine measurement and study of shocks has been kept up to date throughout the year. Now, with the exception of a few records on which great numbers of aftershocks are registered, including the very numerous aftershocks of the strong earthquake of November 4, 1927, our card catalog of earthquakes is complete from the beginning of registration in 1923 down to the present time. These previously unmeasured aftershocks are now in process of measurement.

As a part of the regular routine of measurement we now report the data of *definitely* recorded teleseisms to Science Service for distribution to the U. S. Coast and Geodetic Survey, to the Jesuit Seismological Association, and to other such agencies. Press reports are given out locally when we can supply accurate and definite information. This applies chiefly to the recording of distant earthquakes.

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[1] Extracted from the Report of H. O. Wood, Research Associate in Seismology.

TIME MARKING

The plan for synchronizing the time keeping at all stations by continuous chronographic comparison of all the time-marking station clocks with the dot-and-dash signals of some one commercial radio station has been in use since July 1929 at all stations except that on Mount Wilson. (The station time-marking clock on Mount Wilson is a Riefler precision astronomical clock.) This system has proved its great worth, and improvements have been made in it which will be referred to below, but it is not a perfect system, there is a certain amount of unavoidable *irregular* variation, both in the running of the time-marking clocks at the stations and in the rotation of the recording drums—both those used in registering shocks and those used in the continuous comparison of the station clocks with the radio dot-and-dash signals. Also there are unequal lags in the operation of the relays. However, with this system the uncertainty of a single reading is seldom so great as a half second and usually it is within a tenth or two. Notwithstanding these defects, this system of reducing the time-marking at all stations to a common basis has been thoroughly justified. This is proved by the fact that the intrinsically superior time-marking at Mount Wilson when compared with that at the Seismological Laboratory is less satisfactory than is the case with comparisons among the inferior station clocks by means of the radio method. The radio system will soon include Mount Wilson also, so that all stations may be referred to this excellent clock. Since the system has been in operation, the reduction to standard time has been made a part of the regular routine of measurement. Consequently a considerable body of data bearing on transmission-times, and so on wave-speeds where the origin and length of path can be determined or approximated, has become available.

At the Seismological Laboratory we continue to mark radio time signals sent out from NSS at Annapolis, from NPG at Mare Island, and at times from NPL at San Diego, on the seismograms by automatic relays. These are usually marked at 9. a.m. and noon, frequently at 10 p.m. and occasionally at 7 p.m. Pacific Standard Time. Automatic radio time signals also are marked on the records written at Mount Wilson, usually at 9 a.m.

SHOCKS RECORDED

Routine measurement and study of the shocks recorded has discovered more than forty new epicentral tracts during the twelve months here under report. In a few instances the newly identified areas are located so near to others found previously that it is possibly a better interpretation to consider the findings indicative of enlargement or extension of the active areas. For example, there is a marked clustering of such tracts along the San Jacinto fault zone extending northwestward from the vicinity of the Superstition Mountains.

A few of the epicentral tracts determined previously have been quiet during the present year. Most of them, however, have been active. Some of the older and some of the new epicenters have been correlated with many shocks; others have been correlated with but few shocks and in some cases with but one shock only.

Out of the many hundreds of earth disturbances registered, the great majority of which are true local earthquakes, the following shocks may be selected for special mention.

(1) July 8, 1929, at 8:46 a.m. P.S.T. This shock manifested slightly destructive intensity in a very small area at and near East Whittier, California. Within 24 hours 156 aftershocks were registered. This shock was favorably located for critical investigation, and it has been the subject of intensive study, now nearly completed. The result will be offered for publication at an early date.

(2) September 26, 1929, at 12 noon P.S.T. The origin of this shock was beneath the Mojave Desert. It was perceptible to people in Pasadena.

(3) November 28, 1929, at 11:49 and 11:53 a.m. P.S.T. These shocks originated beneath the Sierra Nevada a little to the north of the Southern California province. There were numerous aftershocks.

(4) January 15, 1930, at 4:24 and 4:34 p.m. P.S.T. These shocks, felt widely in Southern California, originated beneath the central part of the San Bernardino Mountains. Slight damage resulted at places separated by many miles, but there was no major damage anywhere. The center of the shaken area was in the midst of a mountainous tract with crystalline rock at the surface practically everywhere. These shocks will be the subject of thorough study.

(5) February 7, 1930, at 3:23 p.m. P.S.T. This shock originated in the Peninsular Range just south of the Mexican border.

(6) February 25, 1930, at 6:30 p.m. P.S.T., with many aftershocks. This shock caused slight damage within a very small area at Westmoreland in the Imperial Valley.

(7) March 1, 1930, at 3:44 p.m. P.S.T., with many aftershocks. This caused some damage at Brawley in the Imperial Valley.

These two shocks in Imperial Valley were studied in the field and the results will be published in correlation with such instrumental study as is possible in these cases, where the origins are not very favorably located for critical work. It may be noted that the shock of February 25 was of greater energy than that of March 1, although the damage at Brawley was more considerable than that at Westmoreland.

Within the Southern California province the San Andreas Fault has continued quiet for the most part. A few small shocks have originated along its course from San Bernardino east through San Gorgonio Pass. A shock on September 22 originated, apparently, near Little Rock east of Palmdale. And at least three sharp shocks have originated along the rift near its conspicuous flexure in the neighborhood of Frazier Mountain west of Tejon Pass.

Northwest of the Southern California province a considerable number of shocks have originated on the San Andreas Fault, or its branches and associated neighbors. The most noteworthy of these occurred on October 15, 1929, felt at and about Coalinga, and on November 26, 1929, felt sharply in San Benito County and the adjacent region.

The San Jacinto Fault has continued active at intervals, with epicenters distributed along it from southern Riverside County into Mexico. The evidence is strong that the shocks of February 25 and March 1 originated on this fault in the neighborhood of the Superstition Mountains.

A considerable number of small disturbances registered at Haiwee and Tinemaha appear with little doubt to be associated with the somewhat complex fault zone which marks the eastern limit of the Sierra Nevada, but exact location is difficult from the data of these two stations only. The shocks of November 28, however, appear to have originated west of the mountain crest. Also shocks felt near Brown in Inyokern Valley may have originated east of the major zone.

There is little doubt that an active source in the southern Panamint region has been determined.

A small shock on April 23, 1929, and a series of shocks, very perceptible in the immediate vicinity of their epicentral tract, on May 12, 1930, are attributed with considerable probability to the Agua Caliente fault southeast of Warners Hot Springs.

As an unexpected outcome of the study, a considerable number of shocks have been shown to have originated beneath the Mojave Desert along a belt of known faults, which extends from the general vicinity of Barstow to that of Ludlow.

Shocks also continue to occur along the southern edge of Mojave Desert north of Little San Bernardino Mountains, possibly on the Pinto fault.

A number of small shocks have originated beneath the San Pedro Channel. Some of these were felt very noticeably at points along the coast.

During April 1930, a considerable number of earthquakes, some of which were quite strong, were recorded from a source in the Gulf of California at about 29° N, 113° W. This activity was more violent than that of any nearer source during the year. This source was also very active, though to a less degree, in April 1929.

Several artificial disturbances have been recorded, and some have provided useful data.

A powerful blast set off at the flood control dam-site at the forks of the San Gabriel River on June 26, 1929, was recorded at all five of our stations then in operation. Two lesser blasts set off at this site were also recorded usefully; and a few minor blasts were detectible on the records.

A major blast set off at a cement quarry near Victorville on June 15, 1929, was recorded at several of our stations. It was at first taken to be an earthquake and located on the basis of the instrumental data at a point very close to its true site. It was learned later from an engineer who visited the Laboratory that the disturbance was a blast.

The numerous groups of small disturbances on the records written at Riverside have been identified positively as due to blasting at two quarries not far distant. A blast larger than usual at one of these, on April 1, 1928, wrote an illegibly large record at Riverside while very small motion was recorded at Pasadena.

Since the beginning of experimental registration in 1923, blasts have been recorded from nine different sources, at nineteen different distances between blast and seismometer station, ranging from about 4 kilometers up to 195 kilometers. The blasts have differed greatly in magnitude and the records differ markedly in quality and the degree of control, of time, etc. Notwithstanding this, an intensive study of the whole assemblage carried out recently has brought out very consistent results with useful determinations of phase and wave-speed. This study has been completed. It will be prepared for publication in the near future.

DEVELOPMENT OF INSTRUMENTS

From the beginning much thought has been devoted to the devising of a system, or systems, to rotate recording drums uniformly.

As a result of this development we now have available four superior systems for rotating recording drums, three of which are operated by storage battery so that they will continue to work for some hours or days after failure of the commercial power supply. These are the original 10-cycle system, much improved, the 60-cycle, 50-watt tube system entirely free of electrical contacts, and the 60-cycle controlled motor-generator system. In addition is the auxiliary 60-cycle, 50-watt tube assembly which will operate accurately as long as energy can be supplied to it from the commercial lines.

After the suitability of the dot-and-dash system for synchronizing the time-marking had been established it was deemed desirable to design a radio-receiver better adapted to this purpose than the one used in preliminary experiments, which was unsatisfactory because it was too sensitive to small changes in adjustment and because it required too many tubes and made too large a drain on the station batteries. The new receiver requires three tubes only and also minimizes static impulses.

A vertical-component local-earthquake seismometer, an outgrowth of the one mentioned in the report for last year, has been in operation for several months. The mechanical element consists of a cylindrical inertia-reactor of 10-kilogram mass supported by a helical spring of such stiffness as to give the system a period of 0.2 second. Critical damping is provided by a perforated disc suspended in a bath of oil. The electromagnetic response unit is a modification of the common telephone receiver design, with the addition of a shunt across the pole pieces of the magnet. The output of this unit is connected to a galvanometer of 8 seconds period which is greatly overdamped. The combined electromagnetic and optical magnification is approximately 50,000, for displacements of the inertia-reactor of period shorter than 10 seconds. Because the magnetic unit is responsive to the velocity of the displacement of the inertia-reactor there is no conspicuous shift of the recording light-point on account of temperature variation or elastic-yield effects in the spring and mounting. As a whole the assembly is such that the response curves with respect to amplitude and to phase displacement are similar to the present short-period horizontal-component torsion instruments.

The magnetic-response element developed for the vertical seismometer just discussed has proved interesting as a general micrometer for measuring small movements. The ease with which it can be set up, its ruggedness and high sensitivity should render it useful in many fields. The sensitivity is easily brought to the point where a movement of the armature of 6×10^{-7} cm., or 0.01 the wave-length of sodium light, produces a displacement of 1 mm. on the photographic record where the mirror of the galvanometer, is at a distance of one meter. The effective magnification is 200,000. It thus compares favorably with the best interferometers.

The condenser microphone developed by E. C. Wente of the Bell Telephone Laboratories has proved to be the most precise instrument for the measurement and recording of sound waves in air so far invented. It seemed desirable, therefore, to test the adaptability of this device to seismometry. Although the electrical principles are the same, it was found necessary to design the mechanical assembly differently. In the vertical-component instrument which was constructed, the condenser is formed by two circular brass plates 4 inches in diameter separated about 0.2 mm. The lower plate is fastened securely to the pier while the upper is suspended by means of a flat spring and is insulated from the ground. The natural period is about 0.3 second. The viscosity of the air between the plates is made to provide critical damping. The upper plate is grooved and perforated to secure the correct value for the damping. The two plates are connected to a battery through a very high resistance. Changes in the capacity of the condenser resulting from change in the distance separating the plates—relative movement in the vertical—produces an electromotive force across the resistance. The sensitivity is approximately 2500 volts per centimeter displacement between the plates. For local earthquakes this voltage is impressed upon the grid of a suitable electron tube whose output is connected to a short-period galvanometer of the oscillograph type. The response of this instrument to displacement will be uniform within very narrow limits for disturbances whose frequency ranges up to several thousand cycles per second.

Observations on higher-frequency earth movements have been made with a condenser seismometer. These were of two kinds, with an untuned galvanometer and with a sharply resonant tuned galvanometer. The sensitivity was increased by a 2-stage vacuum tube amplifier. Under these conditions it was found desirable to move the instruments to a point about 6 miles northwest of Pasadena to get away from traffic disturbances on nearby boulevards. In the new location there was no time, day or night, when, with the untuned galvanometer, traffic movements were not observable, although between 3 and 4 a.m. they were greatly reduced. Disturbances could be observed, due to the passage of a single automobile for a distance of more than a mile along a boulevard in the vicinity. With the resonant vibration galvanometer in place it was possible to single out frequencies in the earth movement in the range 10 to 60 cycles per second. It was found that there was movement in this range at all times of the day and night but with a minimum between 3 and 4 a.m. When an automobile engine in the vicinity, starting from rest, would reach a certain speed the light spot would go completely off the scale. As the speed was increased further the spot would return. From the appearance of the galvanometer response over several weeks time it appears that, at this location, it can be found at all times that some automobile engine is running at the right speed to cause a deflection of the galvanometer when tuned within the range of 10 to 60 cycles.

Some work has been done with an elastic wave-displacement device to act as a seismometer; and with an electrically maintained balance-wheel to serve as the controlling element of a time-clock, but the outcome of these experiments is not yet ready for report.

The methods for making small, thin, plane-parallel mirrors, which had reached an advanced stage at the end of last year, was early brought to a successful conclusion. Excellent small mirrors can be prepared by following the processes of the method, and such mirrors are now available for the torsion seismometers.

The double-cylindrical-lens optical system was designed to afford a light-point some six times more intense than that obtained by use of a spherical lens system, but the light-"point" yielded by the cylindrical lens system proved to have an appreciable area which was elongate in the direction of the recording line. When disturbed, a very narrow "band" of light, as distinguished from a "point," sweeps across the paper at right angles to the direction of travel or rotation of the recording drum. In consequence it is still doubtful whether this system, which is an improvement in respect to intensity of illumination, can be made to write a sufficiently fine line. The system is adequate for time determination to the nearest second but it is doubtful if tenth-seconds can be determined with sufficient accuracy.

An attempt was made to redesign the long-period torsion seismometer so as to eliminate the effect of a small iron impurity in the inertia-mass, which had been found to affect adversely the zero position and the proper period of the instrument with the damping magnet in position. For the usual inertia-mass was substituted one in the form of a plane sector of a circle attached, at the center of curvature of the arc, perpendicular to the torsional suspension. The magnetic damping field was then made perpendicular to the sector (parallel to the suspension). Notwithstanding the theoretical advantage of this arrangement, various inertia-masses tried in this way turned out to be very inhomogeneous with respect to the content and distribution of magnetic impurity, so that this sector type of inertia-mass proved to be little if any better than the vane type previously used.

However, this sector type did furnish a means for making a careful study of the distribution of magnetic impurities. It was thought at first that these might be confined to the surface, and be due to careless handling; but a series of examinations after successive treatments with acid and cleansing solutions showed the impurities to be distributed throughout the material rather uniformly. Consequently the preparation of copper free of magnetic impurity was next considered, but further experiments demonstrated that the period and zero position of the long-period instruments are disturbed so easily and to such an extent by magnetic impurities in the field of the damping magnet that even if specially prepared copper were available ordinary handling might contaminate the material to such an extent that it would be little better than good commercial copper.

As a result of this experience a long-period air-damped torsion instrument was constructed in which an extremely light aluminum vane enclosed in a small brass housing was added to a somewhat modified inertia-mass. The whole was adjusted to provide damping near to the critical value. In routine use this instrument has worked well at periods of 12 to 15 seconds, and at longer periods in experimental running. Like all long-period horizontal pendulums it is sensitive to tilt and to microseismic motion, and at times the diurnal drift is large enough to confuse the registration.

A strong-motion torsion-type seismometer for horizontal motion has been worked out which consists of two small inertia-masses not quite equal in mass, attached to a horizontal bar equidistant from the (vertical) torsion suspension. The system is thus slightly unbalanced and will rotate when affected by a force at right angles to the bar. Magnetic damping is used.

The distance from the mechanical axis of rotation to the instantaneous axis of rotation is determined from the period when the suspension is placed in the horizontal. The instrument will record optically, and it has been adjusted to have a magnification of unity at a scale distance of one meter. The testing of the instrument has been completed and it will soon be installed to await the action of a sufficiently strong shock.

Great need is felt for a simple device for measuring the "intensity" of an earthquake, inexpensive enough to permit very wide and thickly placed distribution. Recognizing that the "intensity" is a complex matter, it has long been considered that the acceleration, and the maximum acceleration, may be taken as first approximations to intensity and maximum intensity. Consequently much effort, first and last, has been expended to obtain a simple and inexpensive accelerometer for this use. Dr. J. A. Anderson has experimented with two devices for this purpose, both of which seem very promising at the present stage. One is a radical modification of previous designs dependent upon the overturning moment, such as standing columns. The present design is a *leaning pendulum* which will leave its leaning support when affected by acceleration in excess of a certain value, and make this known by releasing a target or making an electric contact or in some similar way. The second device is a tube completely filled with fluid with a sylphon bellows at each end. This system will respond to acceleration in the direction of its length, and means for recording or indicating the values appear to be available. Neither of these developments is complete, however, so they may be passed at this time with this brief mention.

Thanks to very effective cooperation on the part of Lieut.-Commander T. J. Maher, Field Inspector, U. S. Coast and Geodetic Survey, San Francisco, we have received and made use of a large number of card reports upon earthquakes felt by observers in various parts of California. This cooperative service is developing most satisfactorily and great credit is due to the U. S. Coast and Geodetic Survey and to Commander Maher.

RECOMMENDATIONS

It is recommended that provision be continued:

(1) For further experimental work on vertical-component instruments for the stations already designated.

(2) For the further study of minute-to-minute time signals for simultaneous record at all of the stations.

(3) For further experimental work in the study of cumulative stresses (tilt mechanism).

(4) For two more branch stations at appropriate points to be selected.

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Ralph Arnold
J. P. Buwalda
W. W. Campbell
Arthur L. Day, *Chairman*
A. C. Lawson
R. A. Millikan
Harry Fielding Reid
Bailey Willis

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